Learning to draw: an active perceptual approach to observational drawing synchronising the eye and hand in time and space

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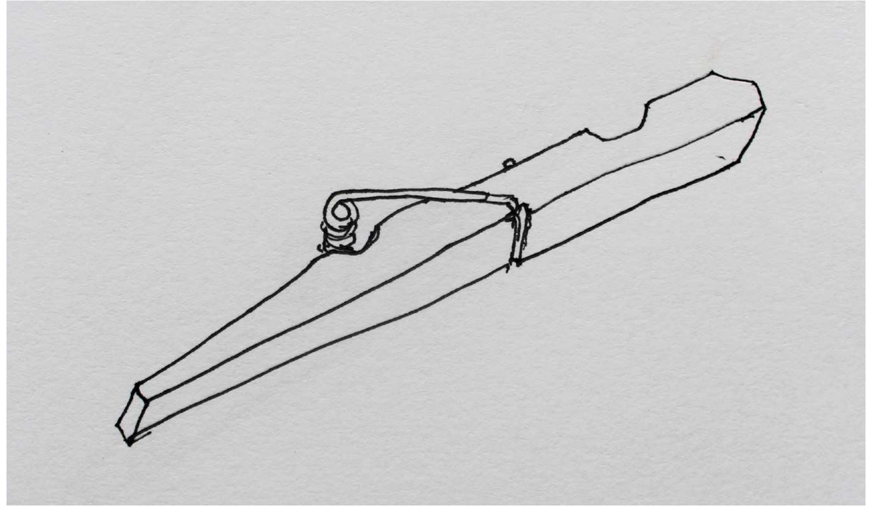

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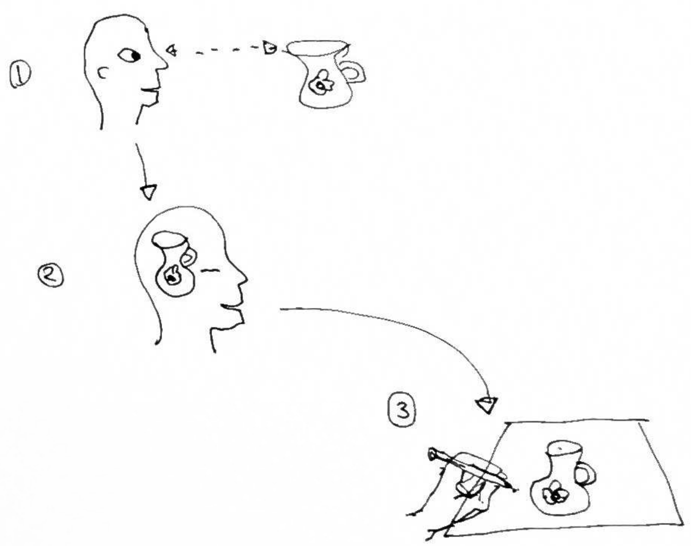
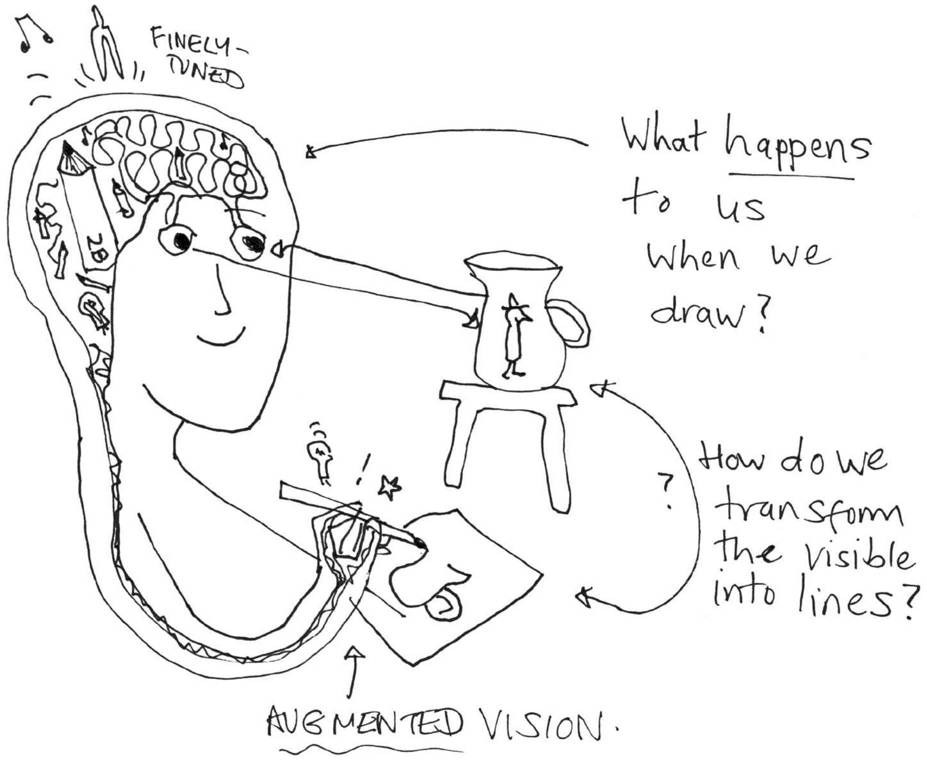
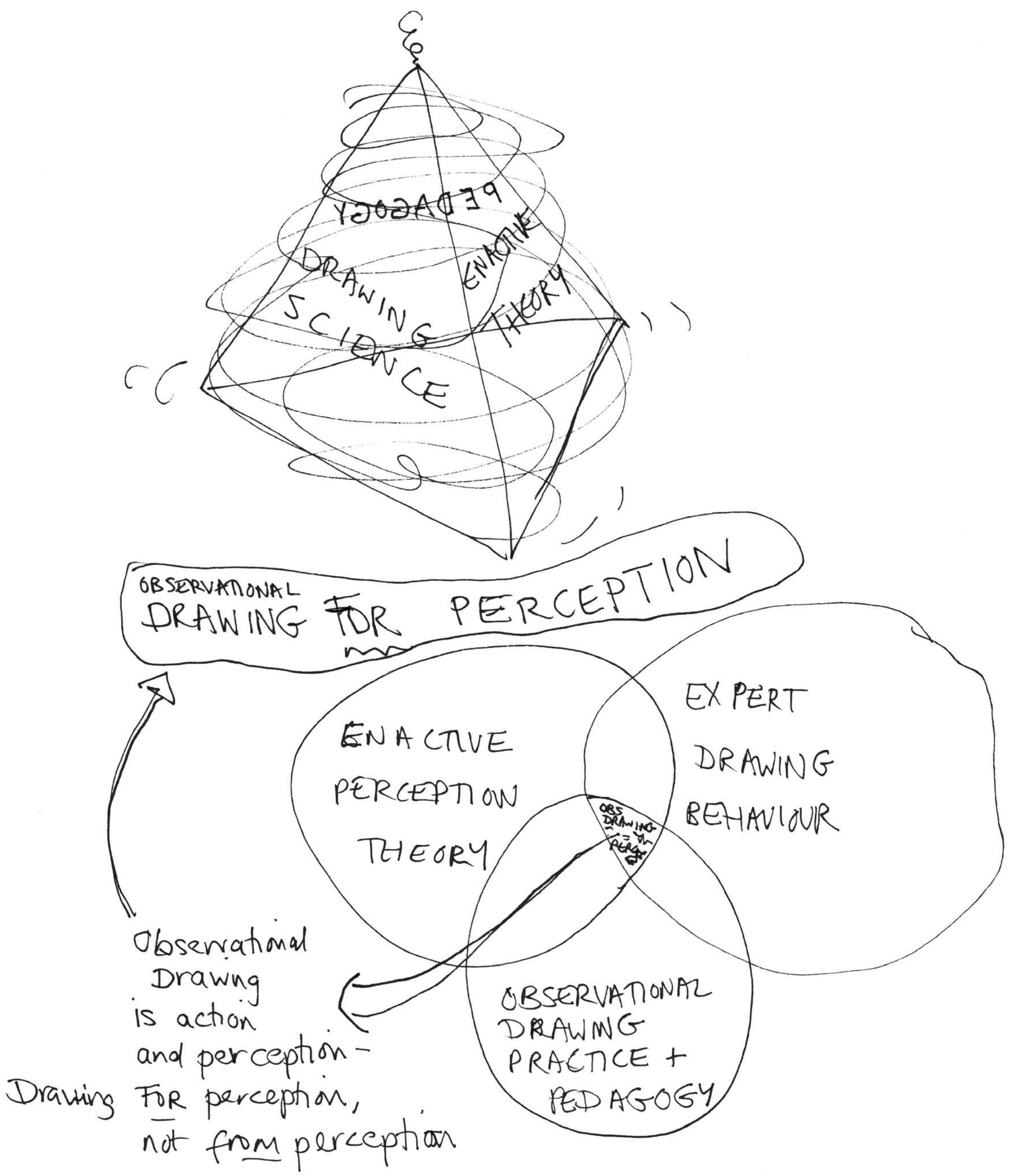
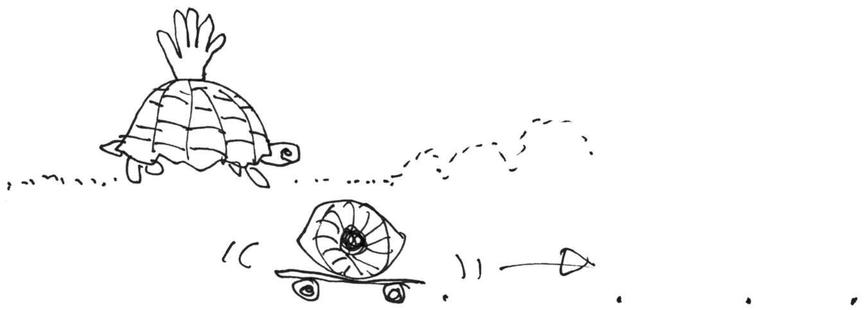




ACTION AND PERCEPTION:
OBSERVATIONAL DRAWING = DYNAMIC SYSTEM FOR COLLECTING, ORDERING AND INTERPRETING INFORMATION.
FINE-TUNING, FOR DETAIL.



Areas of theory and practice under consideration



The eye is fast. The hand contributes detail and a slower, fine-grained perception.

Abstract

What happens when we draw? How do we transform the visible into lines, and how does drawing the lines transform our perception?

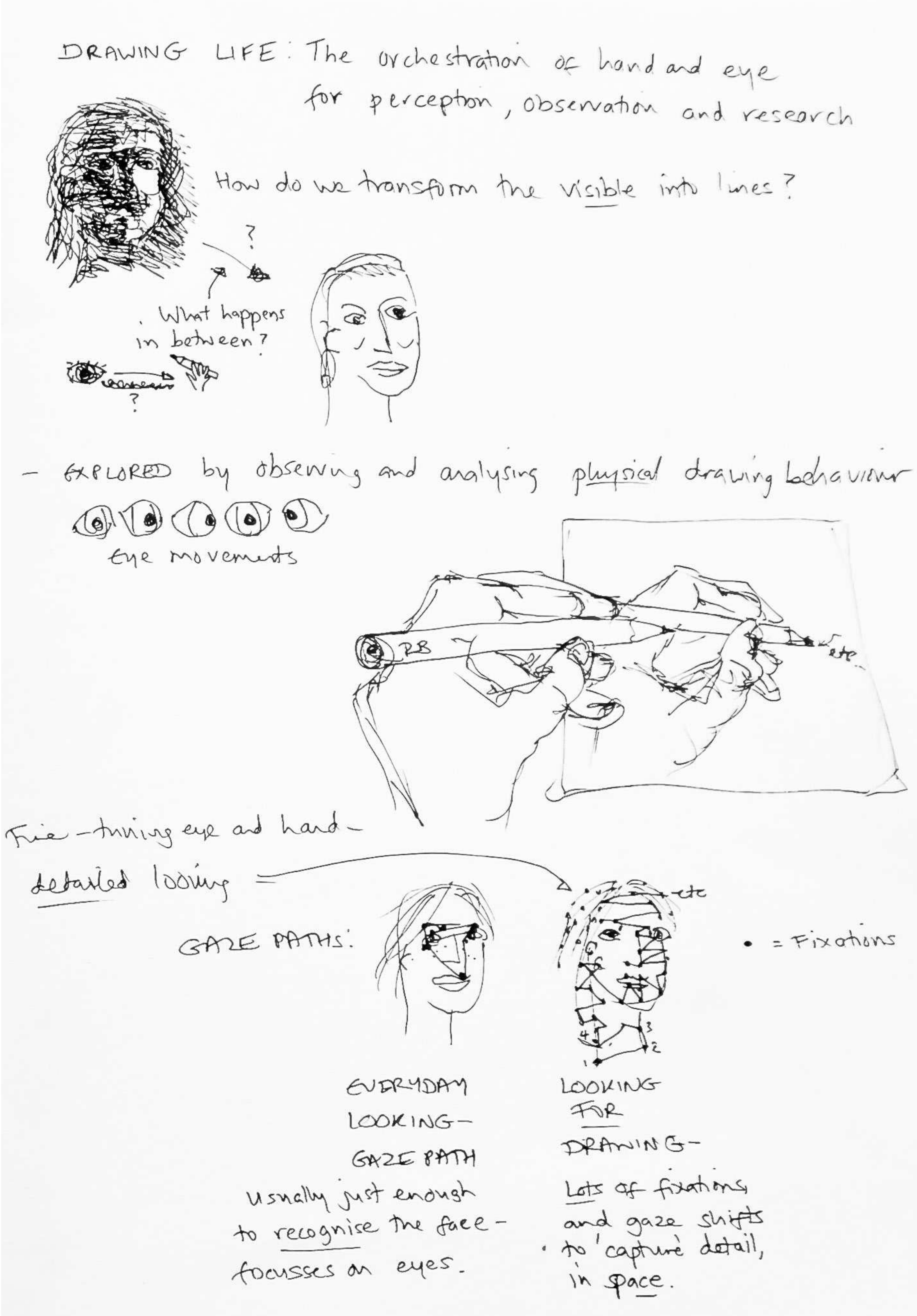
The research explores these questions through analysis of physical behaviour in observational drawing, specifically the communication between eye and hand in time and space. By connecting new scientific models of expert drawing behaviour with enactive perception theory (Noë 2004), observational drawing practice and pedagogy, the thesis concludes that drawing is both an action and a form of perception, finely-tuned for detail by the coupling of the movements of the eye with those of the hand. One draws *for* perception, not *from* perception.

The contribution of the thesis is the development of an enactive observational drawing method, based on the orchestration of eye and hand. While observational drawing is often viewed as more to do with looking with the eye than moving the body, this novel method teaches students to attend to coordination and timing, and its perceptual role. Students learn to draw by learning the dance of the eye and the hand, by developing rhythm.

The thesis positions observational drawing as a dynamic embodied engagement with the world; 'drawing with life' or 'drawing life', rather than drawing from life. The drawing method is defined as presentation (distinct from representation) recognising that perception is transformed by the action of drawing and entailing that it cannot be re-presented, given that it only exists as it emerges. Perception is understood to happen within the movements of drawing.

Drawing is described as a two-way conversation between eye and hand, whereby the eye learns from the hand, and develops a slower 'hand-like' way of looking, that enables drawing. The drawing method teaches students to move the eye in a slower more detailed way, scanning an object, to allow a fine-grained presentation. The project explores the use and potential of drawing in this way as a research tool, and develops methods for future study of the articulation of the body for observational drawing, and of the complex relationship between perception and action.

The conclusion reached is that drawing requires orchestrated movements of eye and hand, and that due to the reflexive nature of drawing, with the action of the hand elucidating vision and in turn influencing the behaviour of the eye, drawing is itself a perceptual process. One perceives from drawing, rather than draws from perception.


DRAWING LIFE: The orchestration of hand and eye
for perception, observation and research

How do we transform the visible into lines?

?

What happens in between?

?

- EXPLORED by observing and analysing physical drawing behaviour

Eye movements

2B

etc

Fine-tuning eye and hand -

detailed looking =

etc

GAZE PATHS:

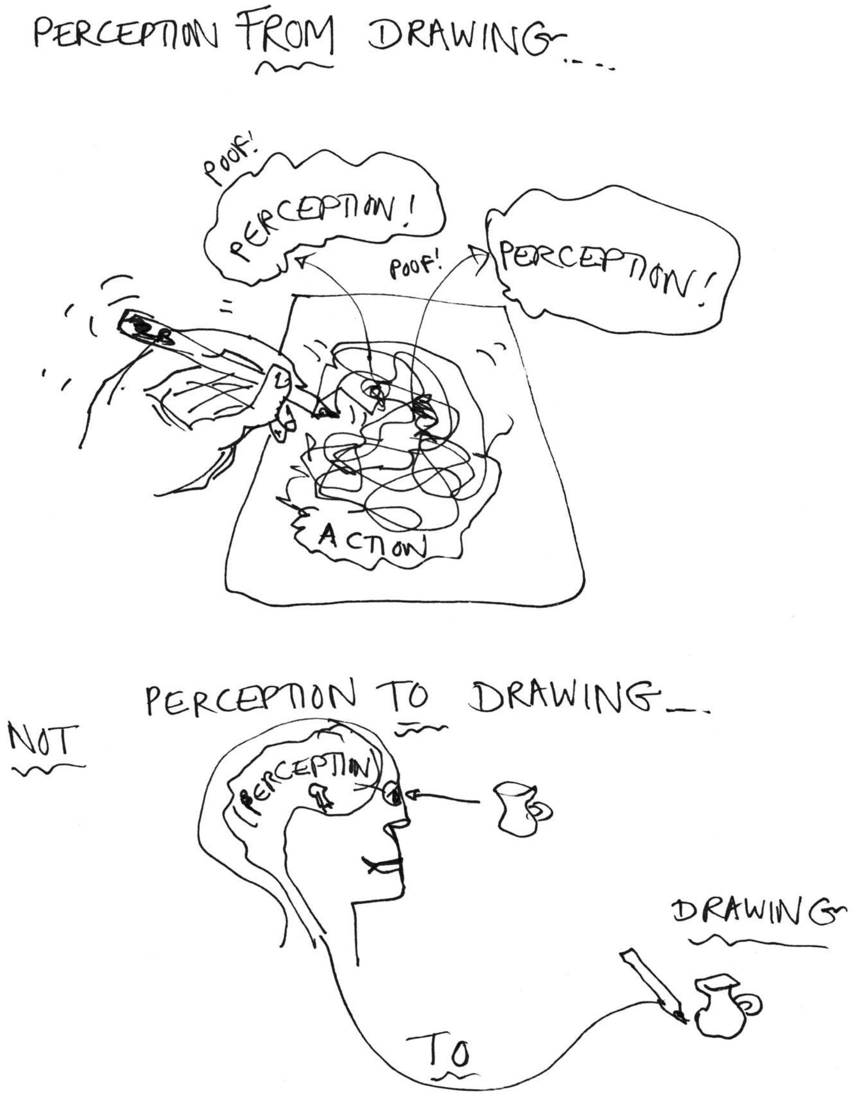
• = Fixations

EVERYDAY LOOKING - GAZE PATH

Usually just enough to recognise the face - focusses on eyes.

LOOKING FOR DRAWING -

Lots of fixations and gaze shifts to 'capture' detail, in space.



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Glossary

The following definitions are by the author, unless otherwise specified.

Perception - The process whereby information about one's environment, received by the senses, is organized and interpreted so that it becomes meaningful. From Chambers 21st Century Dictionary (Robinson 1999 p.1026).

Proprioception - One's sense of one's own body, and how movements and positions within the body relate.

Eye tracking - Video technology and methodology to track and record eye movements and location of gaze: saccades and fixations.

Fixations - Points where the eye stops and 'captures' visual information.

Saccades - Fast movements of the eye, between fixations. Saccades are the fastest movements produced by the human body.

Conceptual bias - The idea that what you know about things can lead to distorted perceptions, such as visual illlusions, or perceiving an elipse as a circle.

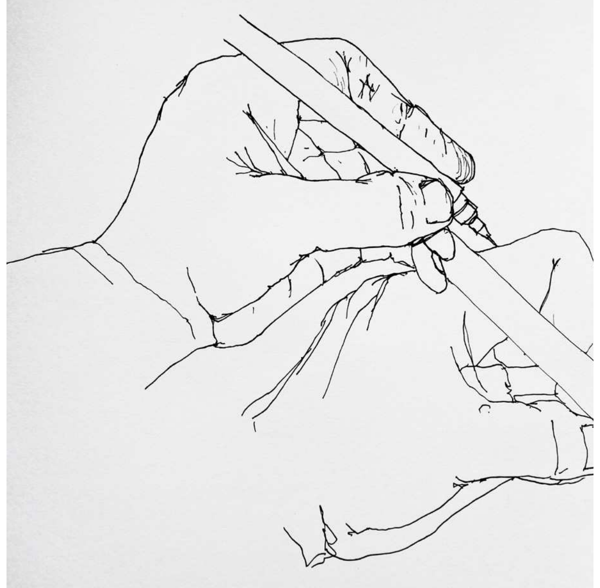


Fig. 1.1 Observational drawing of hands. Reflective practice, to explore eye and hand movements during observational drawing.

Chapter 1 Introduction

Research question

How does drawing practice affect perception?

Research title

Learning to draw: An active perceptual approach to observational drawing synchronising the eye and hand in time and space.

> Drawing something is a complex action; it involves subject and object, perception and representation, eye and mind, and, most obviously - yet too often the neglected components in critical discussion - hand and body. (Rosand 2002 p.13)

> ...the draftsman himself knows the world only by drawing it; the artist "sees" with hands as well as eyes, both sensory extensors of the body in the world. (Rosand 2002 p.13)

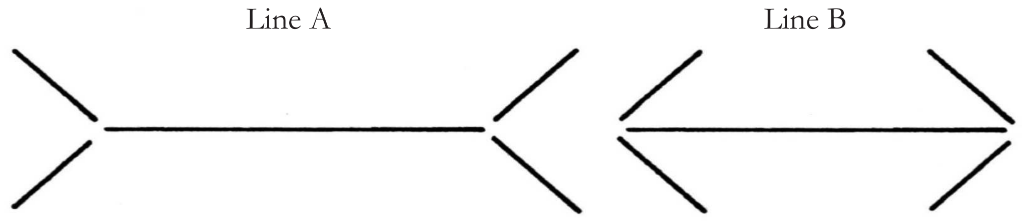


Fig. 1.2 Muller-Lyer Illusion - used to test perception of horizontal lengths of line A compared to line B

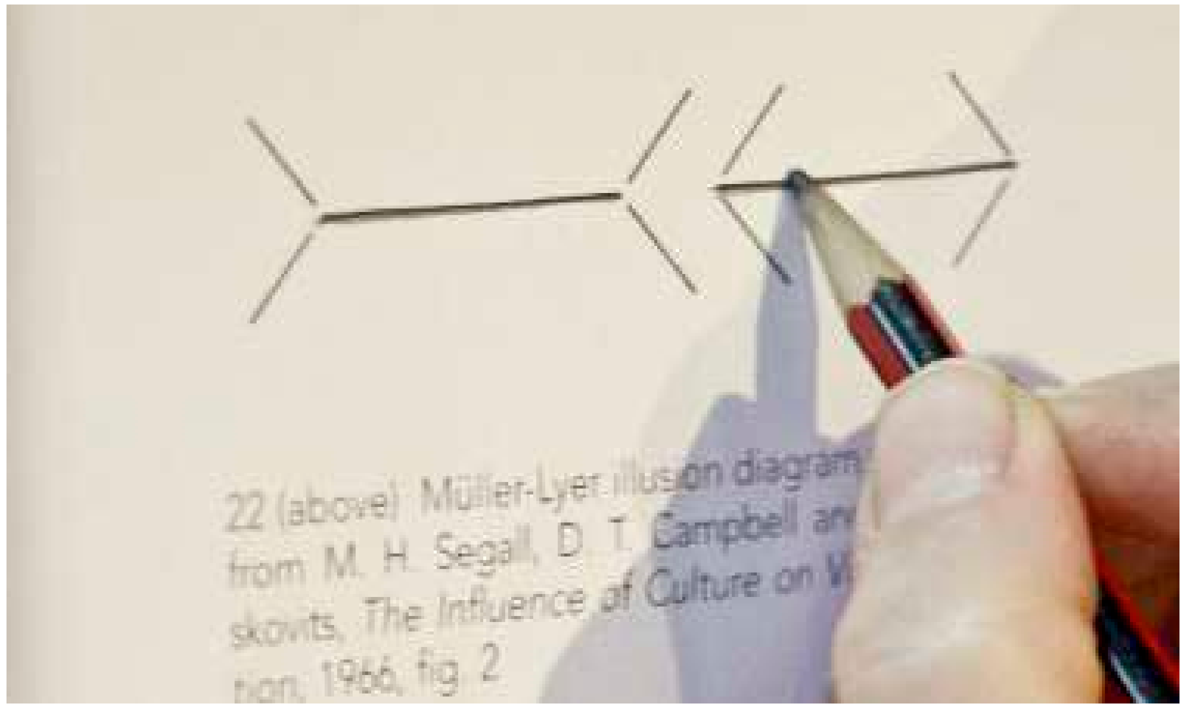


Fig. 1.3 Drawing on the lines - how does drawing on the lines affect the perception of the line lengths?

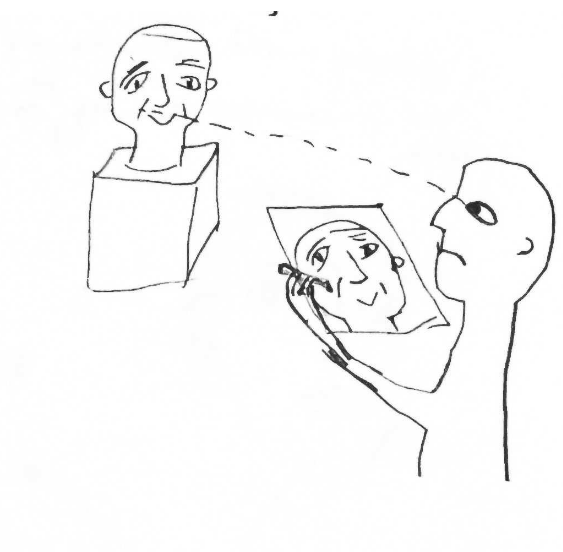


Fig. 1.4 Eye-hand transformation - how do the eye and hand transform a view of the world into a 2-d drawing?

1.1 Introduction

Drawing as a constructive and transformative act

The research question asks how drawing practice affects perception, with the aim of exploring how changes in the way we see the world come about as a result of the act of observational drawing. Can drawing help to dispel visual illusions and enable us to see more clearly? See figs. 1.2 & 1.3 and Chapter 5. The question turns the paradigm of perception to action on its head, looking at how perception stems from action. The study focuses on movements of the body in time, specifically of eye and hand, to offer a physical temporal characterisation of the creative and dynamic act of observational drawing, and to suggest how treading paths between eye, mind and hand may develop new ways of seeing.

Art historian Henri Focillon spoke of the mysterious process from eye to hand:

> Such an alchemy does not, as is commonly supposed, merely develop the stereotyped form of an inner vision; it constructs the vision itself, gives it body and enlarges its perspectives. The hand is not the mind's docile slave. It searches and experiments for its master's benefit; it has all sorts of adventures; it tries its chance. (Focillon 1989 p.180)

The study seeks to articulate this shifting perception by scrutinising the particular role of the hand, and how it communicates with the eye. Notably, art historian Rosand (2002) urges us to attend to the artist's hand, for insight into creative processes. In *Drawing Acts* (Rosand 2002) scrutinised traces left by the hand in drawings of several famous artists (including Leonardo and Rembrandt), interpreting them as records and indicators of artists' processes and states of mind. He writes

> Whatever we may think we know of the mind of an artist like Rembrandt, of his "inner vision", we can know only by attending to the stroke of his pen, that is, to the recorded movements of his hand. (Rosand 2002 p.20)

He refers to the general assumption, held since the Renaissance, that

> ...the obedient hand of the artist gives visible form to an idea conceived in the mind; idea, concetto, pensée – such abstract terms have been constants in the vocabulary of commentary on drawing. (Rosand 2002 p.19-20)

Within this paradigm drawing is understood to be controlled by the brain..Hence, research and theory, across science, education and art and design, largely focuses on cogntive processes as the key to drawing. Rosand argues 'But drawings are made by the hand, and our observations and interpretations must, of necessity, begin with the visible marks on the paper.' (Rosand 2002 p.20) and he urges us to attend to the production of drawing:

> We owe it to our own experience to take the creating process itself as seriously as the created work, indeed, as an integral dimension of the work;

Fig. 1.5 Observational drawing of hand

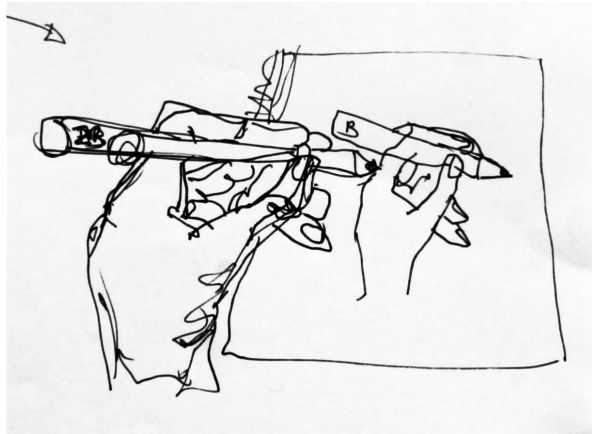


Fig. 1.6 Thinking drawing, about the hand

> as important, we owe it to the draftsman. (Rosand 2002 p.23)

My research follows from this, on the principle that observation of drawing, the verb, offers a new window into creative production, and moreover perception, now made possible by video and eye-tracking technology. I observed hand movements by filming and analysing drawing in progress, and explored how they synchronise with eye movements.

Likewise, drawing practitioner and academic Deanna Petherbridge considers it important '...to examine the manner in which an artist trains the hand in coordination with the eye and imagination.' (Petherbridge 2010 p.11).

On the understanding that perception is created and changed by experience, and that meaning and sense are inherent to vision, observational drawing offers the opportunity to approach the world in a novel way, allowing new meaning to emerge. In other words, there is no innocent eye, but instead a roving 'other wise' eye, and an intelligent hand. To this end the drawing instruction developed here confronts the issue of conceptual bias in drawing (how what you know affects what you see) from a new point of view, by focusing on movement and coordination rather than on mental shifts and efforts to ignore meaning and past experience. The thesis challenges the paradigm that we draw from perception, arguing that we perceive from drawing, i.e. that drawing can be used in order to perceive, rather than depict. The question of how our perception alters due to drawing hinges on how we dynamically interact, rather than what goes on solely in our heads. As Noë argues 'The conscious mind is not inside us; it is, it would be better to say, a kind of active attunement to the world, an achieved intergration.' (2009 p.142).

Accounting for my practical experience, and the science of drawing

The motivation for the study stemmed from a tension I felt about how I drew from life. As a child I enjoyed observational drawing as a solitary activity, which I approached in the same way that I approached maths, as a problem with a solution. This entailed measuring dimensions with my thumb and pencil, from an egocentric spatial perspective. My method focused on accuracy and made visual efforts to forget what I knew of objects, to perceptually flatten the 3-d image to alllow accurate 2-d drawing. Although I found pleasure in drawing accurately, and representing things in a recognisable way, there was an accompanying sense that I was creating distance between myself and my subjects, by flattening them into 2-d images in order to draw. This felt like an escape rather than an engagement with life, and my 2-d observational

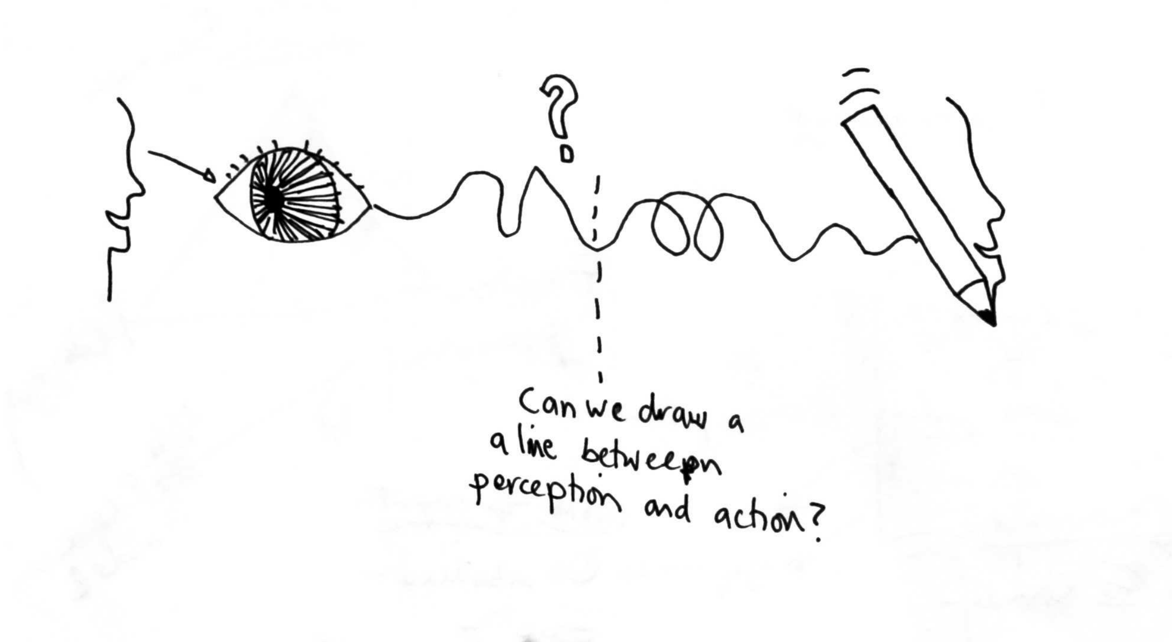


Fig. 1.7 Conceptual drawing, questioning the line between perception and action

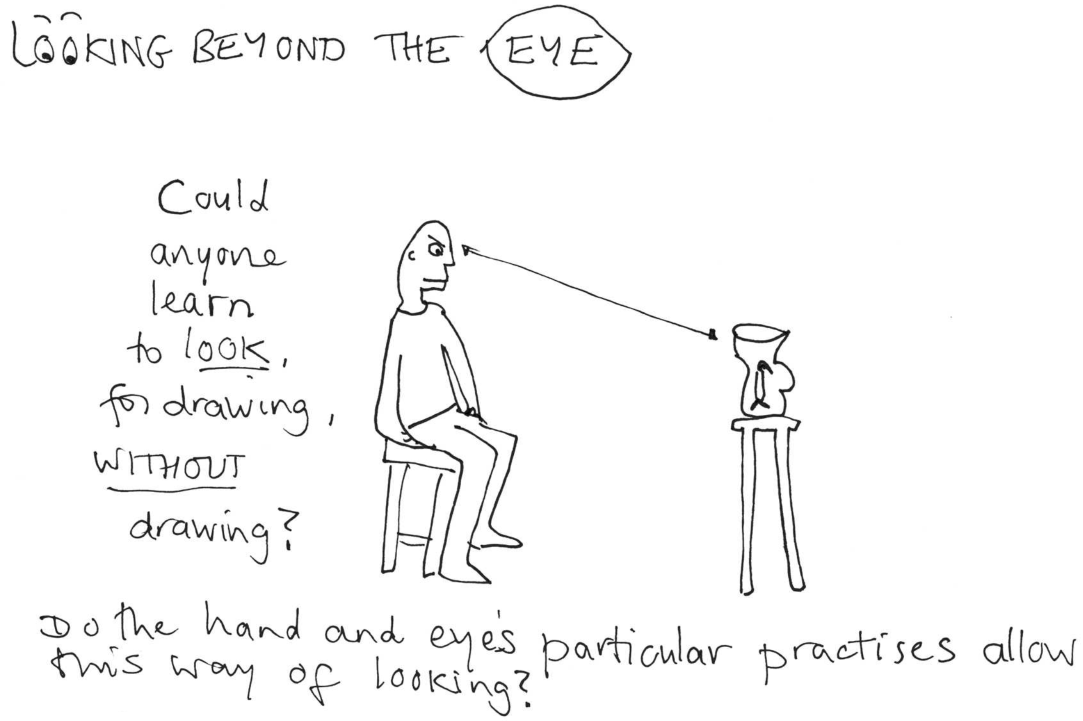


Fig. 1.8 Conceptual drawing, asking how we learn to look at things

drawings often seemed hollow of meaning. I found myself asking why I drew a landscape, when the real thing seemed much more satisfying to look at and experience. Hence, as I developed I questioned the purpose of my drawing practice and sought to develop a method wherein I could strengthen my connection with the 3-d world, rather than distance myself. The challenge was to find a way of drawing where I could still draw precisely, but maintain and explore my connections with objects and the world. This remains a challenge, and the subject of the thesis. Through exploring drawing scientifically and experientially I developed a method that engages with the surrounding world, develops an intense conversation between eye and hand and furthermore reflects on the nature of perception and action, perceptual learning, and how we grow.

My first solution to my distancing problem was to draw from imagination. In life classes I would begin to draw from the model, and then let the drawing run away with itself, no longer attending to visual aspects of the model. It is only through this current practice-led study that I have developed a satisfactory method for observational drawing, that has cut away what I was taught and allowed an overtly physical participation.

I worked as an artist from 1986, on completion of a BA in Sculpture, Edinburgh College of Art. Through my practice I became interested in cognitive processes of drawing, and how observational drawing is taught. Drawing teachers often offer cognitive explanations for teaching instructions, most commonly in the vein of 'draw what you see, rather than what you know', and 'draw the gaps between objects'; all founded on 'innocent eye' theories (Ruskin 1858/1971), that contend that we can see beyond, or under, our accumulated experience to achieve a pure vision. I conducted my Drawing Masters (Camberwell College of Art) research project on the relationship between learning to play the piano from a score and learning to draw from life. I explored the role of motor memory and the possibility of executing a drawing in the same way as a musical performance. This entailed making 450 drawings of a still life. During this time I was working in the Drawing and Cognition Project at Camberwell College, led by Dr John Tchalenko. I continued working there during my first two years of PhD study, exploring eye and hand movements and engaging with current scientific study of drawing. As a drawing practitioner I identified gaps in the science of drawing – most notably the absence of consideration of the role of erasing, and of trial and error processes in drawing. I considered these to be fundamental to the process. Learning to compare your drawing with the object you are observing is a key perceptual skill - probably the most significant perceptual element of the process. As explained below for the most part science boxes drawing with other perception-to-action, eye-to-hand skills. This has been a productive avenue of research, shifting the focus from the innocent eye to the role of movement. However drawing is a special case, in that it is reflective, with the action being integral to the perceptual process. I propose that we reframe drawing as perception in action, rather than as perception to action. I establish this critique by explaining an enactive view, which is well developed in terms of perception theory (see Merleau-Ponty 2002, Noë 2004) but not with regard to drawing.

Looking beyond the eye

The dominant paradigm of 'looking' as the key to observational drawing skill did not adequately account for either my experience or for recent findings from cognitive science about eye and hand movements of drawing. Certainly I had no conscious awareness of a visual mental image when I drew from life. The process seemed more one of informed trial and error; looking, assessing, drawing, reassessing, comparing, correcting, and so on. Influenced by this personal experience and by working in the Drawing and Cognition Project my methodological starting point was to observe movements of drawing; of the eyes, hand and body. How does movement achieve the way of looking required for drawing? How tied to motor activity is the possibility of this way of looking? Could anyone learn this way of looking without drawing? Do the hand and eye's particular practices/movements allow this way of looking?

The new science of drawing (Tchalenko et al. 2014 in press) proposes that the execution of drawing is founded not on visual memory but on encoding of visual information into a motor plan for the hand. In other words, what the eye sees is translated into an action plan for the hand. While holding onto the radical idea of the role of a motor plan, I questioned whether the scientific method used was distorting our view of a more integrated process. Does splitting action and perception into eye and hand behaviour and using input output models tend to ignore feedback processes, as well as the potential perceptual role of the hand and body? Are not these sensorimotor processes the means by which we perceive? If so, movement is the means of perception as well as the means of execution of the task. Through interdisciplinary study could drawing be reframed as an enactive perceptual process? This split view has permeated teaching practice as well as scientific methods.

The Chamber's definition of perception, given below, aptly describes drawing itself; a way of organising and understanding our world, a form of insight. This position is consistent with that of cognitive psychologists, who are now questioning the location of thought and mind, asserting that thinking can operate outside of the body, on, for example, a sheet of paper (see Tversky & Suwa 1997, Kirsh 2011, O' Regan 1992).

Defining perception

For the thesis, I began by defining perception according to the Chambers 21st Century Dictionary as 'the process whereby information about one's environment, received by the senses, is organized and interpreted so that it becomes meaningful'. (Robinson 1999 p.1026). To this end I was examining conscious perception, not perception that we are unaware of, hence perception was seen as closely allied with consciousness. I aimed to contribute knowledge of how experienced drawers may use the temporal and spatial processes of observational drawing to make meaning from sensory experience. A focus on accuracy stemmed from an interest in bodily skill and the communication channel between eye and hand, a resonance and mirroring, rather than the objective of producing a realistic accurate depiction; a final drawing. Hence, the focus was on the verb, rather than the noun 'drawing'. Drawing is an especial skill, with the eye being asked to behave very unusually, setting a range of challenges for perception and action. I was interested in the research potential of drawing, to shed light on subjects of study and make unexpected connections, including between perceptual and explorative processes. Noë writes that

> It is now clear, as it has not been before, that consciousness, like a work of improvisational music, is achieved in action, by us, thanks to our situation in and access to a world we know around us. (Noë 2009 p.186)

By completion of my research the perspective had shifted away from perception as something that goes on solely in the brain, an interpretation of sensory information, to perception as a form of consciousness, emerging from active engagement with the world. From this view, observational drawing is a perceptual tool and an attitude, used to extend and deepen engagement. Likewise, Noë believes that consciousness stems from our interactions with the world. He writes that:

> ...we ought to think of perceiving as an activity of exploring the environment. It is not a process whereby a picture of the world is built up in our brain; rather it is the activity whereby you achieve access to what is around you by making use of various different skills (of movement, of understanding, etc.). (Noë 2009 pp. 179-180)

Likewise, Chemero holds that 'Indeed, perception is a variety of action, and a good deal of action is done in the service of perception' (Chemero 2011). It follows that, for deeper understanding of conscious perceptual processes, we should be looking outwards at dynamical

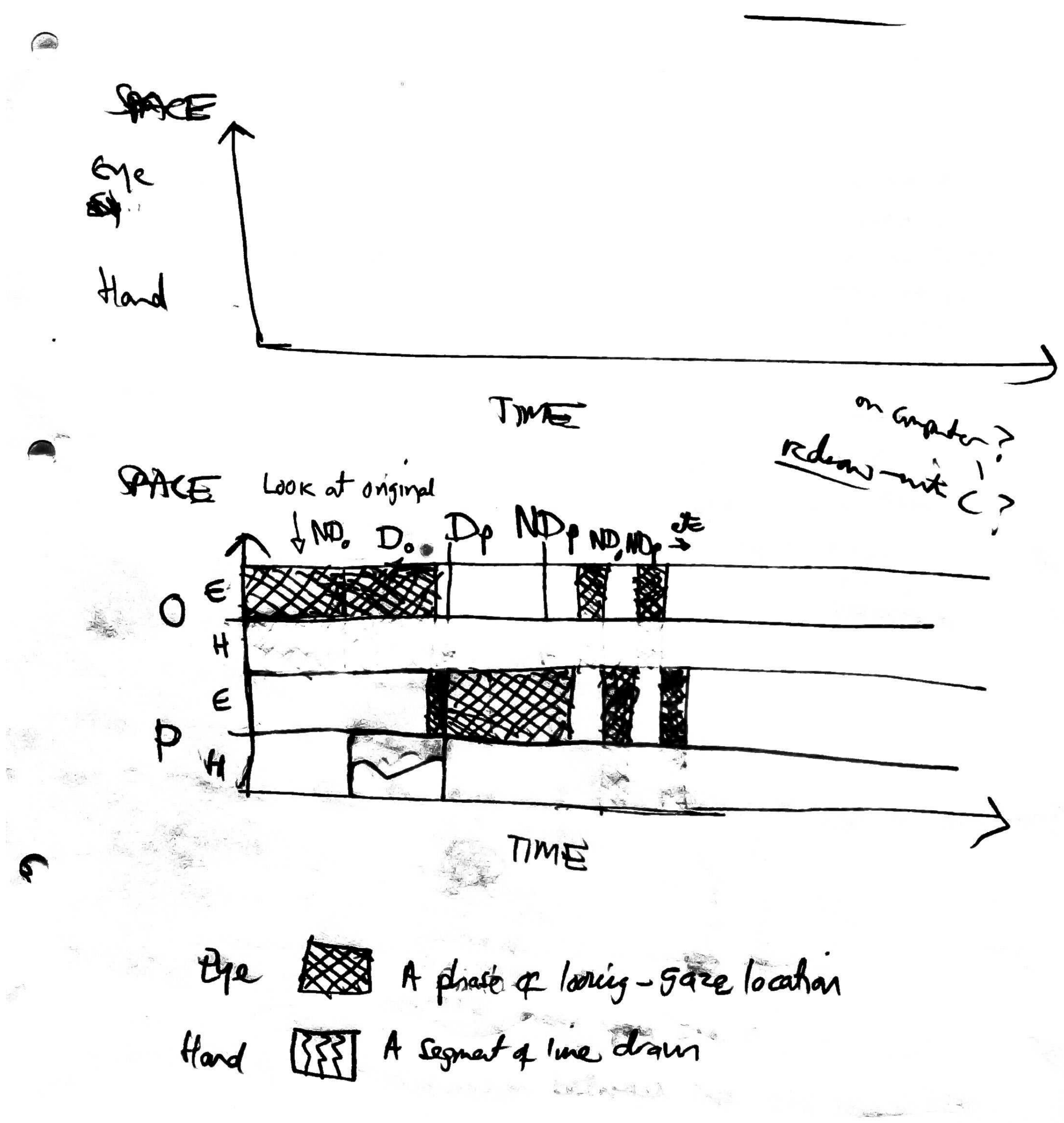
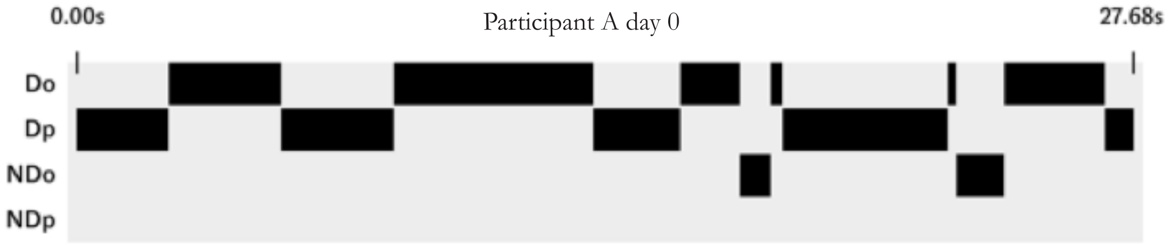


Fig. 1.9 Thinking about drawing in time and space - O = eye on Original, P = eye on Paper, D = Draw, ND = Not Draw,, Do = Draw while eye is on original, Dp = Draw while eye in on paper, NDo = Not Drawing while eye is on original, NDp = Not Drawing while eye is on paper.

systems that we are part of, rather than inside our heads. He writes '...rather, we need to look to the ways in which each of us, as a whole animal, carries on the processes of living in and with and in response to the world around us.' (Noë 2009 p.7).

Questioning assumptions about mental imagery and memory

The study teases apart the process of drawing, to expose common assumptions about vision that may be misleading; modern psychology experiments are designed, and teaching plans devised, on the basis of assumptions about the role of visual memory in drawing. How do new findings about the role of motor memory and sensorimotor plans impact on this? Tchalenko and Miall (Tchalenko et al. 2014 in press) hypothesise that when we intend to draw our brains encode what we see into a motor plan, rather than into a visual image.
Chemero, arguing from an embodied perspective, defines perception as an understanding of relationships, rather than the production of internal mental images, proposing that we think of perception as .'..of affordances, or opportunites for behaviour' rather than of objects. (Chemero 2011 p. 135). He suggests that animals may be embedded in the world in a practical, knowing way that entails less complex internal mental processing: 'The coupling of perception and action and the availability of information about affordances allow animals to guide their behaviour without resorting to mental gymnastics.' (Chemero 2011 p. 160). As outlined in Chapter 2 Tchalenko does not situate himself in the research field of embodied cognition, but what he is making clear is that the eye is involved in complex on-going reflexive communication with the rest of the brain and the body. The current study extended and tested this research, developing an interdisciplinary method for micro-analysis of the drawing process, and particularly of the process of learning to draw.
My quantitative study of the eye and hand movements of Dr Betty Edwards' drawing students, observed as they undertook drawing training, revealed the development of a distinctive eye-hand interaction sequence, similar to Tchalenko's scientific model of expert copying behaviour (Tchalenko 2007). The temporal profile of eye and hand interaction emerged as the most interesting aspect of the study, with findings suggesting a fine-tuning of phases of drawing and pausing, and of gazes between original and paper. This led to development of a model for exploration in the drawing studio, detailed in Chapters 5 and 6. Drawing instructions were created, informed by these questions and findings, and explored in drawing lessons. My drawing instruction, outlined in more detail in Chapter 6, entails keeping the eye on the object while drawing, with minimal glances to the paper, thus maintaining as



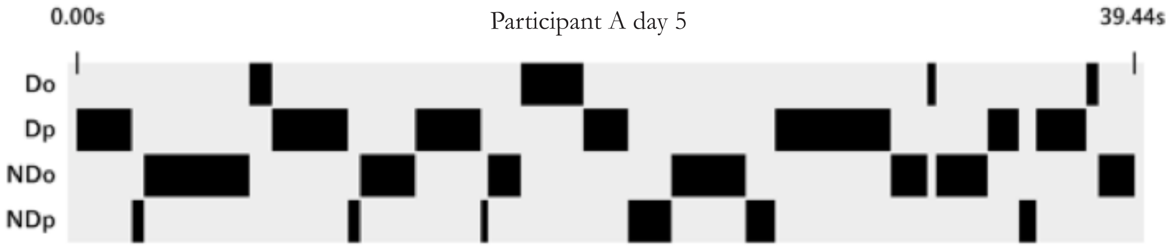


Fig. 1.10 The timing of drawing represented using video editing timelines - D = Draw, ND = Not Draw,, Do = Draw while eye is on original, Dp = Draw while eye in on paper, NDo = Not Drawing while eye is on original, NDp = Not Drawing while eye is on paper.

much eye contact as possible with the object being drawn. This is a motor-based method for drawing, proposing that the moving eye can draw the line rather than visually capture it. In other words the distinction between the eye and hand begins to dissolve: the eye can draw lines, and the hand contributes to vision.

The thesis questions the line between perception and action, initially on the grounds that the eye is constantly moving in order to capture information for perception, and then in order to consider the perceptual role of the hand. Enactive perception theory argues that perception is itself an act. All perception entails movement of some sort; perception is our noticing and registering of changes in sensation. Observational drawing practice makes this particularly clear because the process of drawing does more than externalise and reflect perceptual processes; it contains perception. By watching the 'playing out' of drawing (the process) we watch perception in action, as distinct from perception to action. The eye and hand jointly contribute to perception. Enactive perception theory (see Noë 2004), active vision theory (see Findlay and Gilchrist 2003) and Richard's Gregory's model of visual perception as 'hypothetical' (see Gregory 1997) provide a framework for the study and development of a model of observational drawing that accounts for phenomenological experience of drawing, for the movements of drawing and their contribution to perception. Through this line of argument drawing can be conceived as a special form of perception, which uses our senses and tests visual hypotheses in a particular way. Crucially this relies on the testing of vision by both the hand and the eye, using trial and error, comparing and matching, and erasing and amending lines.

It was clear that the movements of drawing are key to our understanding, and that I should progress by focusing on these observable elements rather than to speculate about 'forgetting', 'innocence', or any other cognitive strategy. How might an awareness of the finely tuned and timed movements of drawing affect how we practise and teach observational drawing? My project was to characterise the action of observational drawing temporally and spatially, and to translate new scientific knowledge of these movements into drawing instructions.

My theoretical premise was that drawing requires an extra-ordinary way of perceiving – an assumption made by many, but with little empirical evidence. The methodological premise was that observation of the movements involved in this form of perception would shed light on the process and offer new understanding of observational drawing.

The fourth dimension – timing of drawing

Regarding movement, the key issues that arose were:

- How drawing plays out in time
- What we can learn from the new science of drawing movements
- The need to break away from outmoded paradigms of disembodied atemporal visual perception that inform drawing practice and pedagogy
- The methodological question of how to observe and reflect on movements of drawing
- The possibility of alternative ways to teach drawing
- The potential uses of drawing for discovery and research as distinct from representation
- The question of the locus of perception, and where we draw the line between action and perception.

In an interview with the author, drawing practitioner and academic Lucy Lyons stated '...I think of drawing as time-based. Interestingly it is never seen as time-based....These events are always time-based.' (Lyons 2013, 25mins 38s). The study aimed to go someway towards redressing this by focusing on the temporal aspects of drawing.

Following from observations of temporal aspects of drawing the thesis proposes that drawing pedagogy teach the 'doing' of drawing, the nuts and bolts of practice, rather than teaching cognitive tricks to subvert everyday vision. By this method one learns to draw by drawing, not by, as if often asserted, by learning to look. To this end a microanalysis of movements was carried out as an empirical quantitative study (Chapter 4), with the aim of revealing information about mechanics of behaviour; of looking and drawing. Following a review of current research, and carrying out my own quantitative study of eye and hand movements, I asked how new scientific findings about the movements of observational drawing might influence contemporary drawing pedagogy and practice. We can now 'look at looking' in new ways, able to scrutinise micro-movements in space and time with video and eye tracking technology. We can also interrogate the interaction between eye and hand. Several psychologists and cognitive scientists have recently conducted behavioural studies to explore the movements of drawing and their contribution to perception. I used their findings as a springboard from which to ask how we learn these movements, and how this new knowledge might contribute to drawing pedagogy, resulting in development of my teaching method that

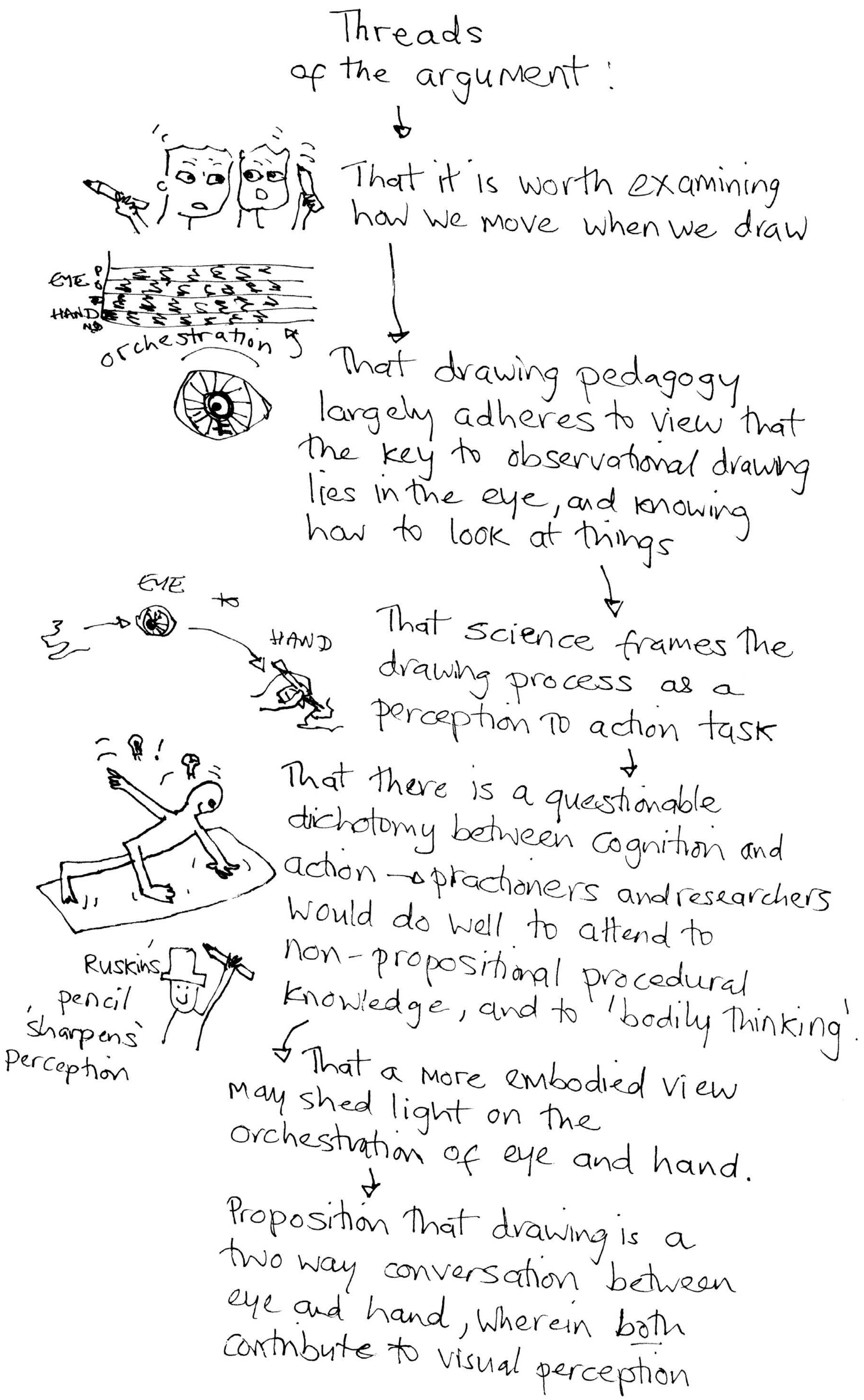


Fig. 1.11 Threads of the argument

hinges on the integrity and motor memory of the human body, and the impossibility of an innocent disembodied eye.

Scientists and teachers often focus on the role of 'conceptual bias', the distorting influence of what you know on what you see. There seems to be consensus that the key to accurate representation is to find a way to 'forget' what you know. This explicit goal is central to drawing pedagogy, with various strategies of looking posited as means to overcome this bias; Edwards (2001) urges us to silence the 'naming' part of the brain by looking for abstract relationships, while Alberti (1435/1991) suggested viewing the world through a flattening grid and Ruskin urged us to see with an 'innocent' eye (Ruskin 1858/1971). However, contrary to received wisdom, Ruskin did not consider the eye to hold the key to drawing. On a close reading I found that he emphasised the role of the pencil and practice in 'sharpening' perception. Similarly, artist Bridget Riley is aware of the contribution of the hand, sensing that her pencil contributes to visual perception. She writes

> It is as though there is an eye at the end of my pencil, which tries, independently of my personal general purpose eye, to penetrate a kind of obscuring veil or thickness. (Riley 2009 p.20)

Contemporary art practice

The relationship of observational drawing to performative drawing within contemporary drawing practice is of interest. My motor method sits somewhere inbetween, focusing on process rather than form, and on development through movement and action. The historical review of gestural drawing conducted by Foá in her PhD thesis (2011) offered context for me to situate my proposed method as a performative enactive practice, despite the comparatively attenuated movement, and hence arguably disembodied character of the practice. Observational drawing raises interesting questions about the speed of drawing, and how a slow detail-focused way of looking may contribute to perception. Theory of gestural drawing tends to focus on fast gestures that capture elusive qualities of bodies and objects, on the belief that this somehow taps into hidden knowledge of the practitioner. This centres on psychoanalytical theory of the subconscious, and what drawing might reveal about the individual. Petherbridge refers to these aspects as '...the psychodynamics of lines and gestural mark-making...' (Petherbridge 2010 p.4). Foá argues that imagination and creativity are found in movement, and conversely that stillness can stifle imagination. She sets a challenge for observational drawing when she states that 'The traditional mark-making onto paper was found to keep a distance between the practitioner (observer) and the

Applying science to pedagogy:

A general profile of 'expert' drawing behaviour entails:

More time spent – more pauses – Shorter simpler line segments drawn in one movement (between pauses) – coordination of eye and hand, in time and space.

↓

Tchalenko's model of drawing execution can be usefully applied in drawing practice and pedagogy

↓

Observational drawing can be taught using instructions about movement and synchronisation of eye and hands

Fig. 1.12 Argument thread about how drawing science can be applied to drawing pedagogy

subject (the environment).' (Foá 2011 abstract). Interestingly, this echoed my own experience of observational drawing, and was the motivation for my search for alternative ways to draw. While Foá explored a deeper engagement through performance drawing and gestural movement, I chose to remain in the arena of observational drawing, aiming to show that it can be embodied and engaged, and in a way that sheds light on perception in action. Foá believes that 'mark-drawing' is a translational process in which 'an idea in the mind's eye or the perceived eye directs the hand to mimic that idea in marks onto a surface.' (Foá 2011 p.1). This echoes the conventional view that I was challenging, wherein the hand performs the eye's idea, and the eye leads the hand. She calls it a repeat. 'The hand endeavours to repeat the idea in the mind, as marks on a surface in the world, and in this way drawing is a performative process.' (Foá 2011 p.1). From my perspective drawing does not repeat. It creates an original event, with the drawn line being both a new idea and a question.

Klee believed that 'Art does not reproduce the visible but makes visible' (Klee 1961 p.76). The thesis argues that his idea applies to observational drawing as well as to drawing from imagination. Drawing creates vision, whether from an internal idea or mental image or from an external object or scene, rather than reveals something that is already there. Ingold writes of drawing

> It does not, in other words, seek to replicate finished forms that are already settled, whether as images in the mind or as objects in the world. It seeks, rather, to join with those very forces that bring form into being. Thus the line grows from a point that has been set in motion, as the plant grows from its seed. (Ingold 2010 p.2)

Drawing for research

The study set up a recursive examination of scientific and experiential findings, taking scientific findings from the lab into the drawing studio for scrutiny, and examining insights of students, teachers and artists in the science lab. Through the method and practice of the research a significant connection was made between the research process and the observational drawing process itself: both require depth of understanding of the object; the research object and the object-to-be-drawn, as well as strategies for attention and articulation of the whole and parts. While it may seem that observational drawing based on movement, and more akin to gestural drawing, may be less 'knowledge-producing', the study finally proposes that an enactive observational drawing method contains potential for discovery and production of new knowledge, as it moves away from depiction towards exploration and research. The characterisation is of the eye and hand as investigative, open to the new, rather than trying to re-present an existing image.

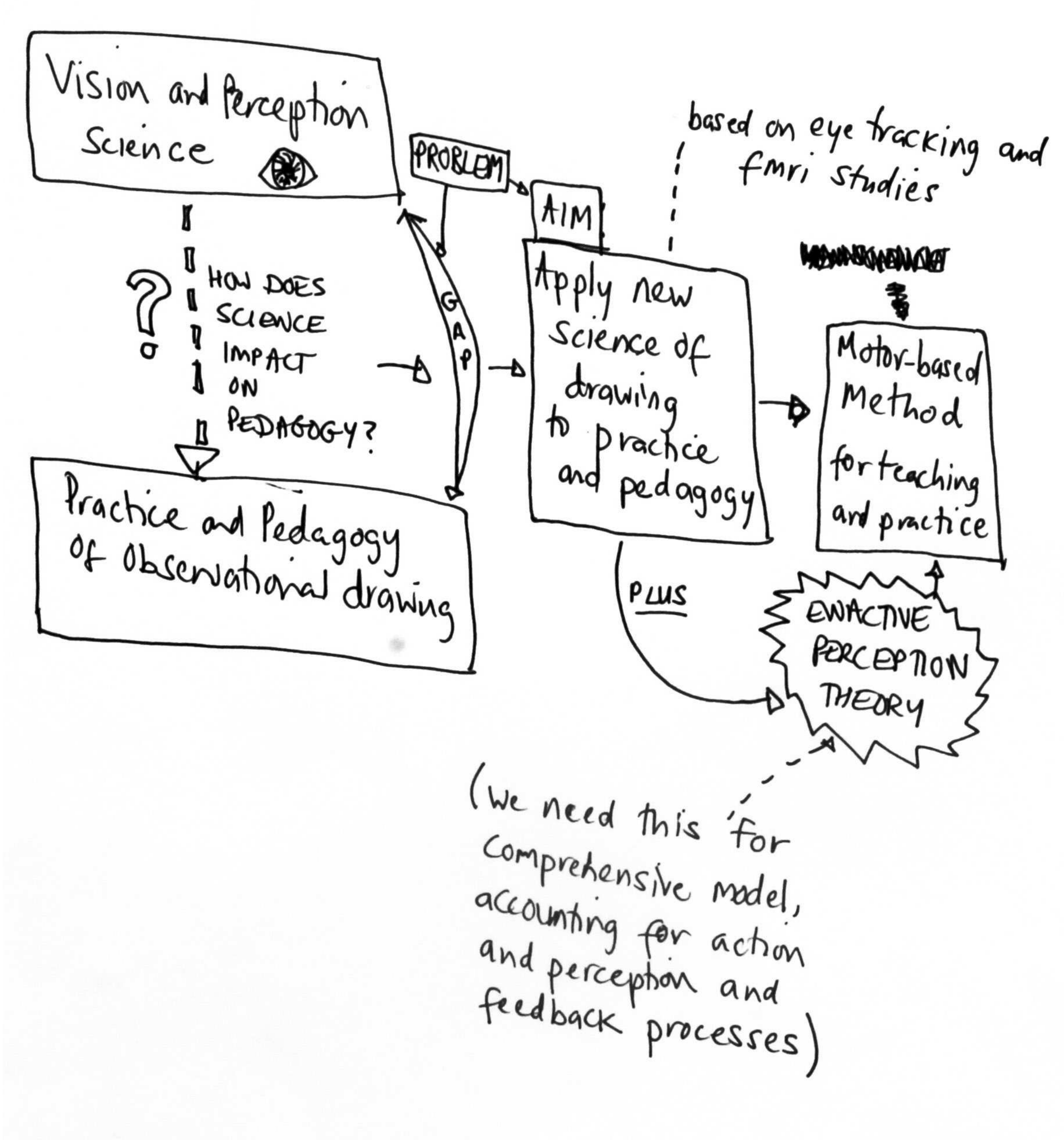


Fig. 1.13 Progression of the thesis

1.2 Aims of the study

The study aimed to develop new observational drawing practices informed by recent findings in cognitive science and to offer a physics of drawing based on pedagogic, behavioural and perceptual theory.

I set out to

1) Characterise observational drawing in terms of movement and perceptual processes.

2) Explore how we learn to draw and the move from novice to expert, and what this may reveal about the perceptual processes of drawing.

3) Explore the relationship between drawing instructions and recent scientific findings.

4) Develop interdisciplinary methods using drawing for research.

In order to do this a comprehensive review of current research established provisional profiles of behaviour of 'novice' and 'expert' drawers, and led to the development of a model of the drawing process that could be explored empirically. In parallel with quantitative case studies I explored new ways of drawing and teaching. Could a deeper engagement with scientific research of drawing inform my practice and teaching of drawing? My drawing practice explored ways to apply scientific theories of visual perception and movement to practice and teaching.

While observational drawing was the research subject, I also aimed to use and explore drawing as a research methodology. The study resulted in the development of a new drawing method with relevance

1) for the teaching and practice of observational drawing

2) as a research tool across disciplines

3) as a new subject for scientific research

1.3 Contribution of thesis

In summary the contributions of the thesis are:

1) The development of a drawing method based on recent scientific findings, my quantitative findings, and reflective practice (see Chapter 6).

2) The development of drawing research practice.

3) A proposition about the perceptual role of the hand in drawing.

4) My quantitative findings relating to the move from novice towards expert drawer show that people can learn to draw. This is a non-trivial matter in science, as to date no longitudinal

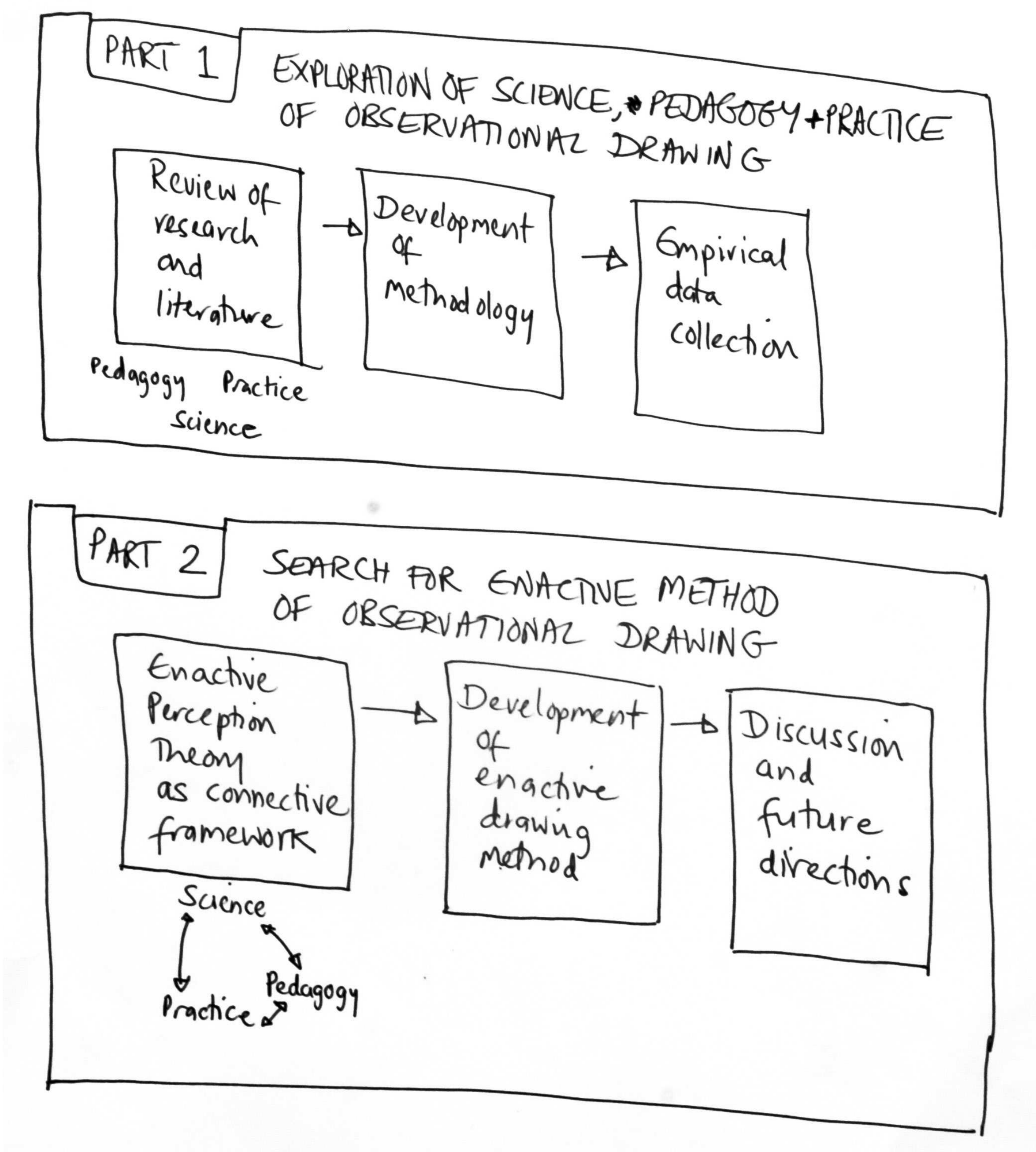


Fig. 1.14 Structure of the thesis - the two parts

studies have been made of the move from novice to expert drawer, meaning that evidence of the move can only be extrapolated from data from 'between participant' studies, and from experiential accounts. My quantitative study of changes in eye and hand movements within participant fitted with Tchalenko's models of novice and expert drawing behaviour (see Chapter 4).

5) Development of interdisciplinary method, using science and drawing to explore a subject (see Chapters 3 and 7), and to begin a dialogue between science and drawing about perception, and roles of the eye and hand.

I set myself a challenge as a visual artist to try to develop an interdisciplinary method that would offer an alternative approach to the study of drawing, and hopefully manage to relate ideas across fields in interesting ways which might lead, in the words of so many drawing practitioners and commentators, to a way of 'seeing things differently'. Hence the research project became itself a drawing process. However the challenge was far greater than I expected, with the process being so alien to my practice, wherein I make art works and drawings that remain contingent and open-ended, asking questions rather than answering. In many ways having to make definitive statements was anathema to me, and has been an immense battle. Even trying to make drawings that communicate explicit information has been difficult. However realising that my drawings were primarily for discovery and research was an important step in the study, enabling me to begin to use drawing as the methodology, rather than the research subject. The process has raised many questions about how we organise thought, conduct research and coordinate activity towards a goal. I remind myself that an 'essay' is an attempt, a trying, from the French 'essayer'. Why I draw is probably because organising thought in a linear narrative is close to impossible for me. Therefore this thesis is a challenge, and represents my attempt to organise and to communicate seven years of exploration of perception, using drawing as the primary tool. I probably went too wide, and not deep enough, so it is dissatisfying in terms of knowledge and analysis and what seems to be a shallow picture. With hindsight I can see that this was inevitable, considering the range of disciplines I was trying to grasp and interrelate. However the hope is that I have managed to articulate something of the nature of observational drawing, and its power and potential for perception and thought. The thesis evidences my struggle to articulate a complex mix of knowledge, ranging from quantitative findings about eye and hand movements, to reflections on drawing as a research method. It can be seen as an attempt by a visual artist to draw things

Fig. 1.15 Thinking drawing - asking how to frame observational drawing

together in an unusual way. Indeed this is one of the roles of practice-based PhDs, to explore new ground and embodied thought, including how we define research and knowledge.

1.4 Structure of thesis

The thesis begins by establishing existing scientific and pedagogic models, then outlining how they were tested empirically and in reflective practice in this study, and finally proposing a reframing of the observational drawing process in the form of an enactive pedagogic method. Part 1, the first four chapters, represent the first stages of research, collecting empirical data, reviewing research, and deciding on a framework for further study. This leads to Part 2, where a more comprehensive model is sought, and theories and practices are linked.

Part 1

Chapter 1 Introduction - outlines the structure of the thesis, and how the questions raised are confronted. It introduces the threads of argument, the methodology and the contributions of the thesis.

Chapter 2 Literature Review - reviews scientific and pedagogic literature on the process of observational drawing. It presents models of observational drawing from science, pedagogy and practice, and introduces the theory of enactive perception. It compares theories of how hand and eye contribute to perception, across disciplines, and identifies gaps in current drawing research and practice.

Chapter 3 Methodology - explains how the working model is explored in the studio to elucidate the detailed, connective looking required for accurate drawing. It outlines interdisciplinary methods, the Edwards' study and accuracy measures.

Chapter 4 Betty Edwards' study - reports on the results of my observational case studies of Edwards' drawing students, before and after undertaking her intensive 5-day drawing training course. It reports changes in eye and hand movements after 5 days of drawing practice.

Part 2

Chapter 5 Towards an enactive drawing model - connects theory from the three arenas of enquiry, cognitive science, drawing education and practice, and enactive perception theory, showing how from Part 1 emerges an enactive view of drawing, and what it entails. It establishes a framework for development of a drawing method.

Chapter 6 An enactive drawing method - recounts how eye tracking and video findings

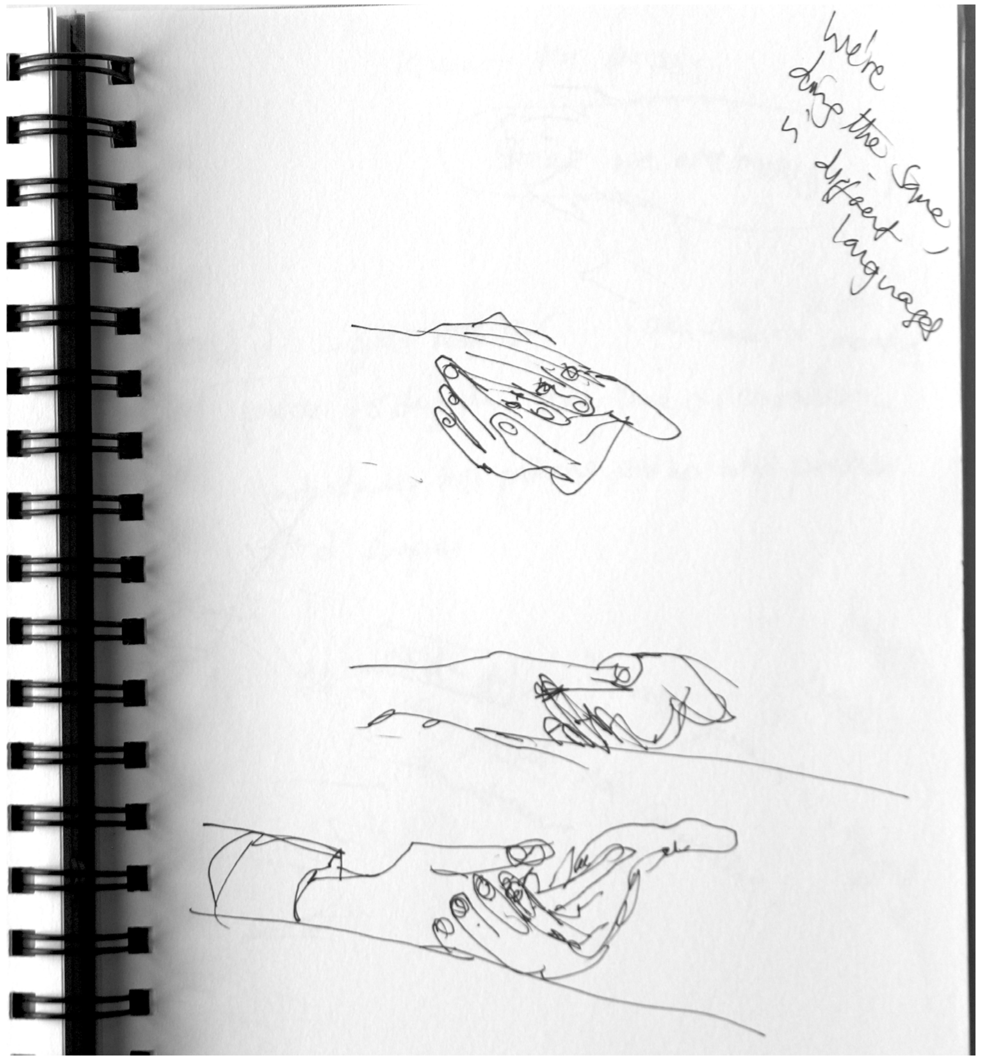


Fig. 1.16 Using observational drawing to observe and think about gesture and thought

were translated into drawing instructions and tried out in teaching situations. The method is built on the eye hand movement research of drawing scientist John Tchalenko, drawing this together with enactive theory and existing pedagogic methods to develop the new drawing instruction and consider its implications and uses, both as a teaching tool and as a subject for further empirical testing. The emerging model distinguishes between phases of physical and cognitive activity, and attempts to interpret the functions of types of action and behaviour. Chapter 7 Discussion - discusses the perceptual role of the hand in drawing, and posits an argument that the hand and eye mutually contribute to vision, that they come to understand one another in an extraordinary way, that drawing perception is a conversation between eye and hand and akin to dancing, in terms of the need for synchronisation in time and space. Methodological arguments and developments are discussed in the final chapter, considering the uses of interdisciplinary methodologies, the need for within-subject longitudinal study, and future research directions, including translational research to explore the uses of drawing. The argument progresses from innocent eye theories to the point where my particular method of observational drawing is defined as perception and research.

1.5 Method of enquiry

Approaching accurate drawing from life as a problem to solve

Observational drawing poses two problems; a theoretical problem of how to characterise perceptual processes and drawing practices, and a practical problem of how to draw accurately and how to teach drawing. By approaching the problem of accurate drawing from these two routes we stand a chance of creating a model of drawing processes that accounts for both scientific cognitive theory and the experience of drawing practitioners, students and teachers. The theoretical problem posed requires, as a first step, a questioning of the long-standing divorce between perception and action, and then a reframing of the drawing process to recognise the bond between them. The practical problem of accurate drawing from life has been considered by numerous practitioners, such as Alberti (1435/1991), Ruskin (1858/1971) and Edwards (2001), who have offered technical advice and instructions relating to perceptual approaches for students. The history and context of these issues are explored in Chapter 2, and appropriate methodologies for further exploration of the theory and practice of observational drawing are considered. The aim is to answer the practical question of how we use our eyes and hands, and how they interact during drawing. The thesis aims to show that motor action contributes to changes in our perception of the external world, and to demonstrate how this manifests itself in drawing behaviour, and the development of observational drawing skill.

Drawing poses a challenge to perception. Tchalenko states 'Beginners perceived the original in a way not appropriate for the task of drawing. This made it difficult to transform the external world, even a two-dimensional group of lines, into an accurate reproduction.' (Tchalenko 2009a p.799). Psychologist Van Sommers argues, in the particular context of drawing a hand, 'I do not believe that normal perceptual commerce with objects is adequate to this task.' (1984 p.132) and that while several styles of perceptual analysis 'would be adequate for recognition… not all are equally suitable as a basis for drawing.'(1984 p.132).

What is an adequate and suitable style of perception for accurate drawing from life, and how do we acquire this style?

Philosophers and historians, such as Merleau-Ponty and Gombrich (see 1977), have linked scientific and phenomenological accounts hoping to get closer to a perceptual theory of drawing. Contemporary scientists Van Sommers, Cohen, Tchalenko and Kozbelt have asked 'what goes on during drawing?' in terms of perception and motor action, hoping to answer the question 'what allows drawing?' and to offer cognitive interpretations of observable behaviour. Bridget Riley talks of a metaphorical eye at the end of her pencil (Riley 2009). However in general the dominant paradigms persist, that drawing requires a special way of looking at things and uses visual memory to capture the image and reproduce it (see McManus et al. 2010).

Can we tie these views together? The thesis uses a mix of practice, quantitative analysis of eye and hand movements, and theoretical study to question the problems and conditions of drawing and to edge nearer to a comprehensive enactive model of how and why we move when we draw. These actions are considered to work as a system, with the research focus on the dynamics and coordination of interactions, in time and space. Chemero sums up his review of Gibson's (1979) ecological perspective: 'I have sketched a picture of animals as active agents, interacting with a world replete with information, and indeed generating information with their actions...'(Chemero 2011 p.160).

Drawing as research and reflection

A distinction between models of observational drawing is between those that aim to make a meaningful picture, and those where the process contains the meaning. The method I developed is relevant for the latter, and hence more attentive to the perceptual means employed, seeking to finely tune the eye and hand. The completed image on the paper may or may not communicate the discovery.

I used drawing in two ways, in reflective practice and as a conceptual research tool to explore ideas, make connections and to organise the thesis structure and narrative. Experience and consideration of the processes of observational drawing informed the research methods, in terms of attention to parts and the whole, checking relationships, adjusting the parts until they work, and become a coherent whole. I worked on chapters in tandem, connecting theory with practice across disciplines and between theory and practice. A thesis needs to work as a whole, and in detail, with consideration of structure and form, as well as content. I struggled to draw the thesis, finding that most of my drawings seemed unreadable, even to myself. I realised that these drawings were my thinking work, and that another type of communicative drawing was needed for the final thesis. I made these close to the end of writing up, at a point when the pieces of the jigsaw had finally fallen into place and when I had a very clear idea of the structure and content. The thesis is constructed and followed using conceptual drawings of every chapter and of the various threads of argument.

I set out to observe coordination of movements in two ways: scientifically, using eye tracking and video, and through reflection and feedback on my own drawing and teaching practice. Analysis was carried out using a range of quantitative software, and hand-drawn conceptual maps and diagrams. Chapter 2 and 3 present context and rationale for my focus on movement as a fruitful way to explore observational drawing, and Chapter 4 outlines the empirical methodology for observation of eye and hand movements, using frame-by-frame analysis of video footage. Much of my methodology was based on methods learnt during working with Tchalenko in the Drawing and Cognition Project, and informed by reflection on my own practice and observation of my drawing students. Chapter 5 presents the findings from this quantitative study.

Framework for quantitative study - video analysis, temporal and spatial

Actions by the hand and eye in space and time were defined as elements of drawing. Spatial and temporal aspects of the drawing process were delineated and behaviour and function were explored in relation to these.

Recording time: Timelines in Final Cut Pro and Adobe Premier, and in addition hand drawn, show the playing out of the process and interactions between hand and eye.

Recording space: Custom-made accuracy software measured spatial aspects of the final drawings in comparison to originals. Video analysis provided data on spatial location of eye fixations and the drawing hand – where the eye and hand are.

Time and space: What I was interested in was how spatial elements of the action play out in time i.e. the interrelationship of temporal and spatial elements of the drawing process. For example, where does the drawer look at the beginning of drawing a line, the middle and the end? When does the drawer look at the paper and when at the original? So the elements explored were 1) Where is the hand? 2) Where is the eye? 3) Is the hand moving? 4) Is the eye moving? 5) When is the eye moving? 6) When is the hand moving? 7) How do those elements interact?

Phenomenological accounts demonstrated an interest in the process of drawing, but it was not until the development of film that the new possibility arose of recording and investigating the process of drawing by observing behaviour. While psychologists continue to test large sample groups for accuracy of drawing, filming the process may be the more revealing avenue, enabling us to inspect the complex interactions between hand and eye and body. Van Sommers conducted an extensive study of drawing and cognition (1984). He observed and documented the process, looking at the order of execution and strategies of drawing, but did not interrogate the micro-level of hand and eye interactions.

Chapter 4 presents results of my within-subject empirical study using video observations of eye and hand movements during drawing. I observed students as they learnt to draw and looked for changes that occurred both in their behaviour and in the levels of accuracy they achieved. The working hypothesis for testing was that drawing practice would affect observable aspects of perception, in terms of eye and hand movements, and that more experienced drawers would draw more slowly, pause more and divide lines to be copied into more and shorter segments. The quantitative study uses video to scrutinise a provisional model of drawing by observing the behaviour of three novices before and after they undergo five days of intensive drawing tuition. Software was designed to analyse accuracy of line drawings and to compare accuracy before and after drawing training. These methods are detailed in Chapters 3 and 4.

1.6 Summary

The study asks what we can learn from the new science of drawing movements and how new knowledge about cognition, perception and learning may contribute to drawing teaching practice. There is not yet a comprehensive picture of the complex processes of observational drawing, which encompass a wide range of methods, and interactions between eye and hand

and perception and action.

As outlined, engagement with the science of drawing led to the idea of teaching the movements of drawing rather than more mind and eye-based perceptual approaches, which I argue are founded on outmoded passive models of vision and a disembodied eye. This offers an interesting alternative to eye-based methods, and a way to communicate very directly between eye and hand, and with the world.

In the following chapter, the contextual review explores why the role of the hand has been downplayed in scientific and pedagogic theories of observational drawing. A lack of connection between perception theory, the new science of drawing, and contemporary observational drawing pedagogy seems to stem from historically dominant paradigms of a disembodied Cartesian eye and behaviourism in science. Science currently frames the drawing process as a perception to action task. While the new science of drawing, led by eye tracking researchers and cognitive psychologists, offers important findings about movement and perceptual skills, I argue that it is not yet offering a sufficient model of observational drawing, because it operates in this 'input output' reductionist framework. New developments in enactive perception theory, when connected with accounts of the experience of practitioners contribute to a more comprehensive model of the movements and orchestration of drawing. Recent cognitive research has examined the behaviour of novice and expert drawers; however my study is the first, to my knowledge, to empirically observe within-subject transformations in novices as they learn to draw and to correlate changes in behaviour with quantitative and qualitative measures of drawing accuracy. My case studies of drawing behaviour of three of Edwards' drawing students, observed as they learnt to draw, suggest that they all moved from novice towards expert drawing behaviour after only 5 days of drawing training and practice. I found that students developed longer pauses between phases of drawing action, in line with recent scientific findings that suggest that longer and more frequent pauses are linked to higher levels of drawing experience (Cohen 2005, Tchalenko et al. 2014 in press). In order to conduct this study a review of current research established provisional profiles of behaviour of 'novice' and 'expert' drawers, and led to the development of a model of the drawing process that could be explored empirically.

To date there is no empirical evidence of practitioners other than myself using my 'eye drawing' method, however both Nicolaïdes (2008) and Edwards (2001) recommend exercises using slow eye movements to follow contours. The hope is that future eye tracking and video observation will reveal more about this slow drawing behaviour of the eye, and that further brain studies will discover more about the perceptual processes and the conversation between eye and hand. It is an open question whether my method is already widely used by drawing practitioners and, if so, whether they are aware of the especial slow finely tuned movement of their eyes and the perceptual contribution of the hand. Part of the purpose of the instruction is to emphasise movement, and to make explicit to students and drawers how perception occurs in action.

An important insight of the thesis is that the drawing hand plays an intelligent perceptual as well as a mechanical role, and conversely that the eye moves and draws, and that an awareness of this can contribute to the practice of drawing. The answer is that you need to look at things slowly and in detail, with your eyes and hands. However this extraordinary way of looking at things requires a complex orchestration, balancing temporal and spatial coordination of eye and hand movements with moments of stillness and the restriction of movement of the head and body, resulting in a particular form of perception. Pauses punctuate the drawing act, giving meaning and prosody to the process. This perspective emerged from efforts to locate phenomenological experiences of drawing practice in relation to new findings and theory from cognitive science about perception and action. The study develops a characterisation of the interaction between the eye and hand that goes beyond traditional sequential vision-to-motor input-output models of the drawing process, conceptualising the interaction as a deepening connection and a shared embodied role for the eye and hand in perception and execution of the task. The hand does not always follow the eye; sometimes it leads. The eye and hand co-operate and communicate. Drawing is a conversation between eye and hand.

My new method of drawing relates to contemporary views of delineation (see Lyons 2009 & 2013) and the role of drawing for research and as a form of engagement, rather than as a visual representational tool. Furthermore the thesis relocates observational drawing as an embodied performative practice with an atttenuated form of movement that tells us much about perceptual processes and is amenable to scientific study. The drawing method developed does not wish to replace existing ways of drawing, but may be useful for specific types of drawing, and phases of drawing.

I looked for evidence of physical changes in means of perception, i.e. in changes in the physical relationship between the hand and the eye and environment within the framework of the body. After identifying considerable changes I considered what this may mean for the perceptual processes of the individual drawer. This entailed exploring the translation process from eye to hand, the transformation of sense to action. Scientists Tchalenko and Miall define this as an encoding of visual information to a motor plan. Through reflective practice an argument built towards the hypothesis that the hand plays a more significant role in perception than hitherto acknowledged in drawing research, and that the pause is an important element of drawing.

The operating principle was to move back and forward from science lab to art studio, engaging in scientific and pedagogic practices, to see what insights and connections emerged from the contrasting methods. This proved productive, specifically in the form of my drawing teaching method, which would not have come about without engagement with scientific study of eye and hand movements, and in my proposition that the eye and hand both contribute to perception, which stems from the phenomenological experience of drawing practice. I began with the idea that I could test some ideas scientifically, but by the end of the study I had realised that where insight emerged was where practice and science converged. Like the eye and the hand, science and reflective practice informed one another and jointly contributed to the final thesis. These questions about the inter-relationship between perception and action, in the specific case of eye and hand movements in observational line drawing, required an approach informed by both science and experience. Experience urges us to step out of restrictive experimental frameworks, and to explore more than can be 'controlled' for.

The thesis raises several questions, notably asking would further longitudinal study, possibly including structural and /or brain scans, reveal changes in the brain of the drawer. The discussion (Chapter 7) proposes development of the methodology, and proposes a longitudinal study in the contemporary neuroscience field of brain plasticity and learning, with practical exploration of the applications of new knowledge about cognition and how we learn to draw. While generally cautioning against attempts to split action and perception, paradoxically the drawing method results in a splitting of processes of drawing that may prove useful for scientific study; between action and pausing, with a specific form of assessment and feedback hypothesised to take place during the pausing phase. An important step in the science of drawing will be to look at communication between the eye and hand, and the questions and answers they ask one another. The conclusion is that assessment and reflective practices play key roles both in research and in observational drawing processes, and that these depend on a fine-tuning of perceptual skills.

Finally, approaching the thesis itself as a drawing, i.e. using drawing as a methodology, facilitated thought and articulation of parts and whole, shedding light both on the research subject and research processes. Rosand writes of Leonardo: 'Drawing, he came to recognize, was his means of seeing and knowing, of relating to and controlling the world.' (Rosand 2002 p.61-62).

Chapter 2 Drawing Paradigms – Literature Review

2.1 Introduction

This introduction outlines the structure and rationale for this review chapter, which gives an overview of teaching paradigms and scientific findings to date about observational drawing, and interrogates the influence of recent scientific findings about drawing processes on observational drawing theory and practice.

In order to create a framework for practical study of the physical orchestration of drawing, the review compares theories, across disciplines, of how the hand and eye contribute to perception and identifies gaps in communication between drawing science and drawing practice and pedagogy. Specifically, it dissects views into motor and cognitive elements of drawing, the purpose being to analayse how much weight and attention is given to motor execution, to temporal aspects and to the role of the hand. The thesis to follow aims to determine what we can learn from the new science of drawing movements, to explore potential uses of drawing for discovery and research, and to develop methodologies to observe and reflect on physical drawing processes.

In line with the objective of connecting theories across disciplines the review is structured by topics, considering views from science, practice and pedagogy together. Section 2.2 defines terms and outlines the drawing research field, looking at existing questions and arguments, and introducing a classification of theories of drawing into practical, theoretical, cognitive and motor. This presents theories that offer some answers to the research question, from across disciplines. Section 2.3 presents accounts of changes in visual perception brought about by drawing, and arguments for why and how drawing practice may affect changes. It examines accounts from drawing teachers, artists and art historians of the transformative nature of drawing and the relationship between action and perception. We find that most teaching is founded on specific ideas about cognition, such as the 'innocent eye', using the right brain, forgetting what one knows about objects, and countering 'conceptual bias' – the distorting influence of what one knows about an object on how one sees and depicts it. These are considered in relation to contemporary scientific findings about drawing and a range of theories and ideas behind instructions and methods. Section 2.4 presents teaching paradigms and how they relate to recent findings from cognitive science. Section 2.5 gives an overview of the main areas of scientific research and theory about the process and movements of observational drawing.

Section 2.6 reviews Tchalenko and Miall's new scientific findings and theories about the process of observational drawing, which attend to movement and physical coordination and to perceptual skills related to drawing practice. Section 2.7 introduces 'active vision theory' and scientist Richard Gregory's model of visual perception. This opens the way for consideration of the role of touch and movement in drawing and perception, and of more dynamic transformative models of observational drawing. Section 2.8 moves to the philosophy and science of perception, examining how enactive perception theory may provide a productive framework for a physical and temporal model of drawing. Section 2.9 looks at associated research methodologies and approaches to the study of drawing, aiming to locate studies that attend to the physical action of drawing.

Section 2.10 shows how the review informs the thesis, explaining decisions and rationale for the research questions and methodological choices. Section 2.11 summarizes the main conclusions of the review process.

As well as raising questions about how new scientific findings and theory might inform teaching practice, the review considers how experiential and reflective practices might contribute to scientific hypotheses formation and the building of a more comprehensive picture of how drawing is carried out, as well as how it is experienced. To this end the review focuses on the execution of drawing and what observable movements may reveal about the relationship between perception and action. The subject of this study is the production of line drawings; however, the review also considers tonal as well as line drawing, as in many cases accounts and findings encompass both styles.

By strategically breaking the drawing process down into motor and cognitive elements the review is able to examine each aspect from the different perspectives, identifying a range of arguments about what makes accuracy in observational drawing possible, in terms of movement, attention and thought. The review demonstrates that models tend to account for either cognitive or motor elements, with few attending to both. Perhaps surprisingly, artists and teachers often lean toward cognitive explanations and strategies, whereas scientists are now suggesting that movement and motor aspects are very influential in the outcomes of observational drawing. However these motor models are often limited by their adherence to a perception to action paradigm, and it is in drawing practitioners' own accounts that we find the most consideration of the role of the hand and how it contributes to perception.

The review covers research from a range of fields that questions the impact of drawing practice on perception. It examines how the three areas of drawing science, pedagogy and enactive perception theory communicate, identifying potential areas where a deeper conversation may be productive in order to move towards an embodied characterisation of observational drawing, and towards new ways of practising and teaching drawing. The recent findings of cognitive behavioural scientist John Tchalenko concerning how we execute drawing, and particularly how we encode visual information, suggest novel ways to approach observational drawing. His new 'motor' model of the drawing process, together with vision scientist Richard Gregory's 'hypothesis testing' model of vision and enactive perception theory offer a framework for better understanding the complex interplay of action and cognition, and for the development of a scientifically-informed method of drawing.

The review shows that contemporary science has taken a significant step in exploring the role of the pencil and hand, by framing observational drawing as an eye-hand skill rather than exploring it only as a creative fine art practice. This resonates with Ruskin's belief that the eye needs help from the hand, and from drawing practice, in order to clarify perception. Gregory's model enables connections to be made between drawing pedagogy, the science of drawing and vision theory. Enactive perception theory (Noë 2004) supports these relationships, suggesting that there may be alternative ways of teaching and practising drawing, hinging on an awareness of motor and proprioceptive processes. As Bridget Riley observes, perhaps artists develop a special sense; an eye at the end of the pencil (Riley 2009 p.20).

In the 1920s-30s artist Kimon Nicolaïdes taught drawing at the Art Students' League of New York. He developed a way of teaching that broke from traditional methods, documented in his drawing manual *The Natural Way to Draw* (Nicolaïdes 2008). He advocated the use of all the senses and, contrary to more common 'innocent eye' paradigms (see Ruskin 1858/1971), proposed that declarative knowledge (knowledge that one can put into words, declare) and meaning mattered; students should bring what they know about objects to the experience of drawing, rather than attempting to suppress or cancel it out. The review shows how his method prefigures enactive drawing methods and how his knowledge and sense of how drawing operates fit with new scientific findings about motor planning and cross modal sensory and perceptual processes.

2.2 Drawing research - Science, practice and pedagogy

Classification of drawing models

Research interest falls into two distinct categories; cognitive ocular 'keys' to drawing accuracy, and motor processes of eye hand interaction. This section of the review progresses from ocular-centric views of drawing, notably 'innocent eye' theories, to scientific models that attend to the movements of drawing, to those that touch on the perceptual role of the hand. The classes of cognitive and motor models of drawing coincide with the division between practical and theoretical models, coming from pedagogy and science respectively. This reveals a bias within drawing education towards claims that cognitive processes hold the key to drawing, with cognition defined as internal mental processes of attention, interpretation and representation of sensory information. Drawing pedagogy is also generally founded on ocular models, entailing that 'learning how to look at things' holds the key to accurate drawing. This means that instructions focus on the perceptual skills of the eye and brain, rather than teaching the hand, or teaching the eye and hand to interact and communicate.

However the findings of scientists Tchalenko and Miall (Tchalenko et al. 2014 in press), and Chamberlain (2013) suggest that motor skills and coordination contribute to drawing accuracy, supporting the intuitive views of artists Kimon Nicolaïdes, John Ruskin and Bridget Riley, all of whom believe that the movements of drawing are central to the perceptual process.

Motor models of drawing can be further classified as either based on linear eye to hand (perception-to-action) models or enactive (perception-in-action) models. Although some drawing theorists and practitioners are interested in enactive and embodiment philosophies, this tends to be explored via experimental and performance drawing, rather than observational drawing (see Foá 2011). For the most part, for an enactive framework for observational drawing we have to look beyond drawing pedagogy to enactive and embodied perception theory, as expounded by philosophers Alva Noë (2004), O' Regan (1992), Gallagher (2003a, 2003b) and Merleau-Ponty (2002). Notably artists McCain (2010), McDonald (2010) and Lyons (2009) offer theses that explore observational drawing within embodied paradigms, and drawing theorist McGuirk (2011) develops enactive drawing theory in relation to knowledge production and thinking processes of drawing.

Cognitive versus motor processes

Observational drawing pedagogy, psychology and philosophy all focus on mental processes, cognitive styles and strategies for drawing, suggesting mental tricks to subvert normal everyday ways of looking. Merleau-Ponty talks of the artist 'freeing' the subject (1973 p.47), In *The Elements of Drawing*, Ruskin urged students to see with an 'innocent eye' (1858/1971 p.13), In Art and Illusion, Gombrich (1977) suggested a psychological process, more complicated than Ruskin's notion, whereby skilled artists build up frameworks of knowledge (schemata) which eventually enable them to draw, while Betty Edwards trains students to 'silence' the chattering mind, thus accessing a visual 'drawing mode' (see *Drawing on the Right Side of the Brain,* 2001). Edwards believes that '…manual skill is not a primary factor in drawing. If your handwriting is readable, or if you can print legibly, you have ample dexterity to draw well.' (2001 p.3). Her teaching method is based on a cognitive paradigm, wherein drawing is facilitated by learning a particular way of looking that depends on mental shifts to draw attention away from the possible distorting influence of what one knows about an object. Her instructions stem from drawing methods going back to Alberti in the 15th Century (Alberti (1435/1991) that hinge on solving the problem of how to make a life-like 2-d representation i.e. how to transform from vision of a 3-d world to a 2-d drawn image. Similarly, in *The Elements of Drawing* (1858/1971), written in 1857, John Ruskin proposes the use of a notional 'innocent eye' to try to see clearly by ignoring prior knowledge of appearances and focusing on the current visual sensation. In the particular context of painting, he proposed the

> …recovery of what may be called the innocence of the eye; that is to say, of a sort of childish perception of these flat stains of colour, merely as such, without consciousness of what they signify,—as a blind man would see them if suddenly gifted with sight. (Ruskin 1858/1971 p.27)

However his teaching instructions emphasise the role of the hand as well as the eye, under the premise that a sharp pencil sharpens vision. This raises the issue of how we define vision, seeing, looking and perception. Section 2.4 which follows examines these definitions and shows that misunderstandings arise from assumptions about what is meant by vision; some use the word vision to refer to a broad perceptual understanding rather than just the information captured by the eye. Therefore we have to proceed with caution and consider possible interpretations of theories ascribed to Ruskin, Edwards and Gombrich (see *Art and Illusion* 1977). A slippage seems to occur whereby their ideas are simplified into a key idea and popularised, even when they acknowledge the complex interplay of cognitive and motor processes involved in drawing from life.

In observational drawing classes teachers, using selective and arguably simplified elements of theory, variously suggest that students forget (Ruskin 1858/1971, Geer 2011), remember, make a cognitive shift (Edwards 2001), attend to detail, or imagine they are touching the object (Nicolaïdes 2008). These are usually explained by teachers in terms of the mind and thought, divorced from physical action, and not elucidated in terms of how to use movement to achieve drawing accuracy. Psychologist Dale Cohen asked 'why can't most people draw what they see?' (Cohen & Bennett 1997) and, as we saw, concluded that 'misperception' of the object (1997 p.671), defined as a distorted interpretation of sensory information, was the hurdle to accurate representation, rather than any problem with manual skill or eye hand coordination. However there are a few examples of experiential accounts of eye and hand movements, with speculations about how these may be related to perceptual and cognitive aspects of drawing, in the writings of artist Bridget Riley and practitioner/teachers Ruskin and Nicolaïdes.

In psychology, much of drawing research that explores the relationship between action and cognition is about design and invention processes, where drawing is from imagination not from observation (See Kirsh 2013, Suwa and Tversky 2009, Kantrowitz 2012a, Goel 1995). This stems from an interest in visual thought processes, and how we can conceptualise and problem solve with external formulations and images. In this way drawing can be used for research, as an alternative way of thinking and understanding (see Chapter 3 for consideration of drawing and sketching as research methodology).

In a recent qualitative study of how art students view and use observational drawing psychologist Chamberlain found that

> Drawing is construed by the interviewees as an internal language, a method of thinking about the visual world. It is used by the current sample as a form of visual note-taking; forcing the artist to think about ways in which to represent what is seen. Many artists use observational drawing as a way to think through and experiment with novel ideas. In this way it does not represent a process of passively collecting perceptual information faithfully translated to paper, but an active selection process designed to deconstruct the visual environment in very specific ways with particular pictorial goals in mind. (Chamberlain 2013 p.61)

In academia much attention has recently been paid to the role of drawing in knowledge production (see Cain 2010, McDonald 2010, McGuirk 2011). Showing that drawing is knowledge-producing receives more attention in academia than exploring the mechanics of the eye-hand craft and the relationship between perception and action. This is probably rooted in the historic split between fine art and craft, with the intelligence and creativity of the former privileged over the bodily knowledge and skills of craft. Complex issues of the value of non-propositional and non-verbal knowledge, and how these can be evidenced, are now highly relevant in relation to practice-based PhDs and emerging research methods (see McGuirk 2011).

Within the contemporary science of drawing there is now a move towards consideration of the physics of drawing. Psychologist Van Sommers (1984, 1995) scrutinised processes of graphic production for keys to accuracy of line drawing. In his earlier study he focussed on observation of drawing behaviour and strategies, while his later study moved on to consider cognition in more depth, by exploring the use of memory in drawing. Physicist Coen-Cagli (2011) studied the coupling of eye and hand movements, and John Tchalenko compared novice and expert movements to ask what 'allows' observational drawing (see Tchalenko 2009a). Van Sommers (1984) and Tchalenko are significant in their approach, as they sideline the issue of what is termed conceptual or perceptual bias, the distorting effect of what you know on what you see. They focus on movements and execution of observational drawing. Tchalenko provides models of expert eye and hand movements, while Van Sommers looked only at drawing execution and production, rather than the contribution of eye movements. Tchalenko and Miall study a lower procedural motor level of eye and hand movement, the aspects to which artists and teachers pay less attention.

In summary, artists and teachers of observational drawing talk more about the act of looking than about the movements of the eye and hand. Ruskin and Nicolaïdes represent notable exceptions, but it is revealing of the bias towards ocular and cognitive views that Ruskin's 'innocent eye' theory is the enduring element of his teaching method. Evidence of differences between novice and expert drawers show that artists possess or develop an unusual, task-specific way of looking at things, and a specific relationship between the eye and hand. Recent findings from eye tracking and fMRI studies support an active view of vision, foregrounding bodily movement in the learning process and in the development of understanding and perception. Tchalenko and Miall (Tchalenko et al. 2014 in press) hypothesise that before we draw, during a preparation stage, our brains encode what we see into a motor plan, rather than into a visual image. Their theory fits within a traditional paradigm of perception-to-action, wherein the eye and hand have distinct roles, with the eye leading the process by receiving information and the hand executing the drawing. Tchalenko is making clear that the eye is part of the body, involved in complex on-going reflexive communication with the rest of the brain and the body. This represents a shift away from a conventional view of the disembodied eye, towards an enactive framework of study.

From outside drawing research, scientists debate the link between perception and action. For example, while Milner and Goodale (1995) considered action and perception to be processed separately in the dorsal and ventral streams of the brain, Gallese et al. (1999) and Rizolatti et al. (1995) believe, from their empirical findings, that there is a less rigid division. They found shared visual and motor function for populations of neurons in the parietal lobes and an interconnection between visual and motor representations, begging questions about accepted distinctions between sense and action.

2.3 Seeing lines - Accounts of changes in visual perception associated with drawing practice

Visual analysis skills

Many artists and philosophers have talked of a change in the way they begin to see things as a result of drawing practice. Historically most of the accounts of this transformation come from art theory and education.

Rosand writes of Leonardo

> A basic linear structure became his way of both seeing and recording, and it is hardly unique in the history of art that hand and eye so acknowledge their mutual dependence. With pen or chalk in hand Leonardo saw better. Through graphic gesture he could make visible those forces of nature that seemed to lie beyond the threshold of normal perception. (Rosand 2002 p.97)

The ability to look at things in an unusual way is often cited as the key to accuracy in observational drawing. There is a large body of philosophical and art historical literature on artist's visual perception, much of it considered seminal (see, for example, *Cezanne's Doubt*, Merleau-Ponty 1964c, Arnheim 1971, Gombrich 1977). There is also wide support for the idea that artists have a distinct gaze; an alternative way of looking that sidetracks everyday ways of looking whose function is to quickly recognise objects in terms of their common characteristics and act upon them. It is held that artists, with intent to draw, look for more abstract features of appearance; lines, light and shadow, and spatial relationships. In *Prose of the World* the philosopher Merleau-Ponty speaks of the artist's approach:

> …the painter throws away the fish and keeps the net. His look appropriates correspondences, questions, and answers which, in the world, are revealed only inaudibly and always smothered in the stupor of objects. He strips them, frees them, and looks for a more agile body for them (Merleau-Ponty 1973 p.47)

In his description of the painter's way of looking, Merleau-Ponty highlights the central issue of how artists look at recognisable things. Does the artist, when drawing, focus on aspects not usually attended to, such as spatial relationships? Do these elements normally go unnoticed (inaudible and smothered)? Do our expectations and preconceptions of the appearance of things get in the way? Is this because the object's function is the dominant factor (smothering subordinate characteristics)? These questions, asked in various forms, underlie most research in this area.

Psychologist Kozbelt found that artists have 'perceptual advantage' (Kozbelt & Seeley 2008 p.149) in that they outperform non-artists in visual analysis and form recognition tasks. They argue that these results can be explained by the way visuo-motor skill operates in artists' methods to overcome top-down conceptual influences – what one knows about an object. They are referring here to how artists encode information from eye to hand, suggesting that they find a way to translate what they see into drawing action that circumvents distortion of the image by conceptual bias. They argue that these perceptual skills stem from the development of

> …specialized spatial schemata and related motor plans [that] guide attention and enhance the perception of stimulus features diagnostic for the identities of objects and scenes in ordinary contexts. (Kozbelt & Seeley 2008 p.168)

They define schemata and motor plans as 'two classes of specialized, expert knowledge [that] ground perceptual strategies' and argue that 'Therefore, the relative performance of artists and non artists in visual analysis tasks indicate genuine perceptual differences.' (Kozbelt & Seeley 2008 p.168).

However Kozbelt's studies focus on the perceptual skills of experienced drawers and on correlating perceptual development with drawing experience, rather than on examining the nuts and bolts of practice, the timing and interaction of eye and hand or how physical aspects of practice affect perception. Specifically, Kozbelt and Seeley (and see Perdreau & Cavanagh 2013) were testing whether perceptual skills of artists who draw from observation transfer into general life, i.e. they 'see things better' all the time, not just when they are drawing. To this end their experiments usually do not involve any drawing. This rests on the premise that perception is carried out by the eye alone and that perception and action can be separated for experimental purposes. In a similar vein an interdisciplinary group of art teachers and psychologists (Chamberlain et al. 2012b) and Chamberlain, in her PhD thesis (2013), focused on the correlation between visual perceptual skills and drawing expertise. Her results, from structural brain scanning tests, suggest that, in line with Tchalenko and Miall's findings, visuo-motor processes, procedural memory and fine motor control may play significant roles in the development of long-term drawing expertise. (2013 p.5)

Glazek found that

> Expert visual artists differ from nonartists in their patterns of encoding to-be-rendered stimuli, which has implications for cognitive processing changes in experts generally.

and

> The results suggest that artists possess both domain-specific and domain-independent advantages, in that they have more efficient visual encoding and motor output patterns than nonartists when rendering, as well as superior visual encoding.. (Glazek 2012 p.155)

However Glazek's method did not differentiate between drawing practitoners and visual artists. Chamberlain found that drawers have distinct perceptual skills. She investigated the neural basis of representational drawing, in a structural brain scanning study (using Voxel Based Morphometry, VBM) of structural white and grey matter differences associated with artistic ability and drawing accuracy. The study revealed 'changes in grey matter and white matter in motor structures in relation to drawing ability, and in the precuneus in relation to artistic ability.' (Chamberlain 2012 p.256). She found that increased volume of grey matter in the left anterior lobe of the cerebellum, which is involved in motor coordination, correlated with drawing accuracy. Her findings, although tentative and from a small sample group, suggest that drawing practice may alter brain structure.

Sharpened perception

Ruskin, contrary to the accepted view that he advocated the 'innocent eye' as the key to accurate drawing, in fact argued strongly for prior knowledge of nature and anatomy, and especially emphasised the role of the hand and pencil to 'sharpen' vision (see Ruskin 1858/1971 p.28). The concept of the innocent eye stems from the idea of a pure vision (what is in science called a bottom-up view), uninfluenced by prior knowledge and experience. In *The Elements of Drawing* (1971), written in 1856-7, Ruskin urged students to see and draw what was in front of them. Two years prior to writing he had begun to teach drawing, and he had himself drawn since his youth. While he does write that sight is the most important element; 'I believe that the sight is the more important thing than the drawing.' and 'For I am nearly convinced that, when once we see keenly enough, there is very little difficulty in drawing what we see...' (Ruskin 1858/1971 p.13), in fact the picture proves more complicated. In his instructions and teaching methods he emphasises practice of the hand and pencil.

He desired that his system should 'encourage refinement of individual perception, to train the eye in close observation of natural beauties and the hand in delicacy and precision of manipulation' (Lawrence Campbell, in Ruskin 1858/1971 p.vii). The hand, for Ruskin, is at the root of drawing, as discussed in more detail in section 2.5 below. This contrasts with Edwards' view, that cognitive keys to looking can unlock the secrets of drawing without the need for extensive drawing practice. Section 2.5 below outlines Ruskin's advice to students, showing that he is an advocate of experience and bodily know-how. His instructions offer a model of experiential knowledge.

What movement might tell us about perceptual 'style'

Psychologist Van Sommers argues that 'normal perceptual commerce with objects' is inadequate for the task of drawing, and that while several styles of perceptual analysis 'would be adequate for recognition… not all are equally suitable as a basis for drawing.' (Van Sommers 1984 p.132). Through extensive observation and video recording of the execution of drawing he asks what are, and how do we acquire, the particular perceptual skills needed for accurate drawing from life. His broad-ranging study, documented in *Drawing and Cognition* (1984), focuses on how graphic production may reveal these suitable styles. Although he recognises the need for a specific perceptual style he does not describe it, rather he focuses on the correlation between observable behaviour and accurate copying and drawing, assuming the existence of this elusive and particular way of gathering information for drawing.

In relation to eye and hand movements Tchalenko found that in general artists used longer fixations when drawing than in everyday life, suggesting that vision for drawing is unusual – a special form of what he refers to as 'visual capture'; the collecting of visual information.

> Beginners perceived the original in a way not appropriate for the task of drawing. This made it difficult to transform the external world, even a two-dimensional group of lines, into an accurate reproduction. (Tchalenko 2009a p.799)

However Tchalenko takes a step back from assumptions about accuracy and conceptual bias, and approaches the problem and question of accurate drawing from the perspective of physical action. This is outlined in more detail below in section 2.5, which reviews scientific observations of changes in behaviour that may correlate with changes in perception.

2.4 Teaching paradigms – Cognitive hurdles and keys to drawing

This section reviews a range of teaching methods, put into context with theories and hypotheses about cognitive and executive hurdles and keys to drawing. Teaching paradigms are mostly cognitively-based, tending towards a disembodied view of the eye and perception, and holding that the eye is the key to drawing. This section examines Ruskin's and Kimon Nicolaïdes' approaches to drawing instructions, and argues that they point to a more embodied view of the drawing process. (Perception theory is explored in greater depth in Sections 2.5, 2.7 and 2.8 below).

Declarative knowledge and conceptual bias impede accuracy

Extensive literature in cognitive science, art theory, art education and philosophy documents the idea that what we know about an object influences how we draw it. This, when talking about drawing from life, has been framed as a problem to be overcome; artists seek to minimise this bias, referred to as conceptual bias because our concept of the object dominates our understanding, rather than our visual perception of it. Teachers propose that students focus their vision on details, on lines and light, and purposefully ignore the meaning of the whole. This has been a recurring concern of artists, teachers and theorists such as Alberti, Da Vinci, Ruskin, Fry, Gombrich and Betty Edwards, and several teaching paradigms stem from this, for example the instruction to 'draw negative space'.

Art historian Ernst Gombrich (1977) tried to understand artists' efforts throughout history, to accurately represent the visual world. He questioned Ruskin's innocent eye theory, arguing that the innocent eye was an unattainable fantasy. He thought that the experienced drawer uses frames of reference from their experience to make sense of what they see. These frames of reference, which he referred to as 'schemas', include acquired knowledge about objects, and, most importantly for the drawer, learnt knowledge about how to look at the object. In psychology these two types of knowledge are termed declarative and procedural, the former being knowledge that can be verbalised (declared), and the latter knowledge of how to do things, which may be tacit, and hard to put into words. He was in agreement with Ruskin, that the drawer needs to look at the object in a particular (different) way, but held issue with the paradigm of the innocent eye. Through close reading of their two seminal texts (Gombrich 1977, Ruskin 1858/1971) it becomes evident that the two positions are compatible, when Ruskin's 'innocent eye' is understood as a drawing strategy and approach i.e. itself a procedural schema. Breaking Ruskin's model down into elements reveals his belief that declarative knowledge, i.e. knowing about the object and its function, also plays a significant role in accurate drawing.

While declarative knowledge is more often, as outlined above, cited as an obstruction to accurate drawing, Ruskin advocates the acquisition of a catalogue of information about nature, and believes that this knowledge will help with drawing. Gombrich' s notion of schema posits that artists have both procedural and declarative frameworks that enable accurate representational drawing. Psychologist Kozbelt supports this theory and has begun developing and testing it empirically. As mentioned above, central to his thesis is the idea that motor plans, i.e. the encoding of sensory visual information into a plan for how to move the hand and pencil, reduce the bias of prior declarative knowledge about the object (Kozbelt 2007). These various theories all focus on the eye as the key to solving the 'conceptual bias' problem, suggesting cognitive strategies of visual attention to overcome the influence of knowledge on perception.

Tchalenko states that his own recent findings on novice drawers both contradict and confirm Cohen's view about 'misperception' of the object:

> The notion is contradicted because, under these circumstances, it is unlikely that they used prior information on what a "typical" left arm seen from the back looked like. The evidence suggests that they attempted to reproduce Gaudier-Brzesca's lines but could only do so with errors of size, proportion and shape. On the other hand, the notion is confirmed because perception of the original, nevertheless, seemed to be at the root of copying inaccuracies. (Tchalenko 2009a p.799)

The important point here is that misperception can occur even when someone does not have a preconception caused by what they know about the object. A 'misperception' may be of the shape or position of a line. This raises the possibility that misperception may not be based on conceptual bias but rather on a lack of perceptual skill to see what is there. This connects with Gombrich's theory of frameworks of knowledge that enable artists to draw accurately, as well as the idea that drawing entails a complex interplay and flexible application of new and old knowledge, appropriate to the situation. This is further expounded by Mark Johnson's (1987) examination of how schemas are adopted and how they operate. This points to the idea that experience, and how we learn from and apply experience, are the key to development, and hence to transformation.

> …in order for us to have meaningful, connected experiences that we can comprehend and reason about, there must be pattern and order to our actions, perceptions, and conceptions. A schema is a recurrent pattern, shape, and regularity in, or of, these ongoing ordering activities. These

> patterns emerge as meaningful structures for us chiefly at the level of our bodily movement through space, our manipulation of objects, and our perceptual interactions. (Johnson 1987 p.29)

Using Tchalenko's terms, inappropriate ways of perceiving are often considered to entail the giving of meaning to the object, which blocks accurate drawing because an idea or concept of the object is drawn, which may not match the particular view in front of the eye. While Van Sommers presents findings demonstrating that meaning has an 'impact on executive strategies' (1984 pp.95-114) in untrained artists, specifically in the sequence of graphic production, for example, drawing the egg cup before the egg, he does not conclude that such identification necessarily leads to distortion. He only briefly considers the role of conceptual bias, for example, a concept of what a thing looks like (an archetype or canonical view), or knowledge of what it does (its function). He refers to this as 'semantic contamination' and 'subject matter bias' (1984 p.4). He states that he did not find any conclusive evidence of bias affecting drawing accuracy (possibly because he was not looking for it) but that he does not rule it out as a factor.

However he argues that in some cases understanding an object may lead to greater accuracy, and he demonstrates this in tests of the process of drawing of knots. He found that participants drew more accurately thanks to their knowledge of formation of knots (1984 pp.153-156) Knowledge of what is possible, and of physical processes and situations can contribute to, rather than detract from, accuracy of drawing. Here we find a connection between his and Ruskin's point of view. The issue is not as simple as one of seeking a pure innocent vision, or ignoring what you know. Van Sommers' research on the physical elements of drawing brings attention to the complexity of the influence of these various forms of knowledge on accuracy of drawing, and the necessity to consider the effects of executive strategies. Interestingly Betty Edwards' drawing course includes a session teaching about how light falls (see Edwards 2001 p.194), suggesting that despite wide-spread emphasis on a notional pure bottom-up perception and on 'drawing from perception', artists acquire a battery of know-how and understanding of physics and nature. While Van Sommers begins a discussion on the issue of 'subject matter bias' he is reluctant to draw any conclusions, this not being the focus of his research. He does however consider it a serious issue, despite difficulties in directly linking 'failure in performance to a failure in perceptual analysis' (1984 p.131); he believes that there is evidence from '…the nature of errors in drawing and copying that something associated with perception is often involved.' (1984 p.131).

Betty Edwards and the right brain

Edwards believes that drawing depends on perceptual skills that can be learned most easily by making a cognitive shift, from a verbal declarative mode to a visual spatial mode. She emphasises that this is a new way of looking, distinct from everyday vision. Furthermore she asserts that this can be learnt quickly, either through her book (2001) or on one of her intensive 5-day courses for beginners. Edwards teaches five perceptual skills, that she believes are needed to draw any perceived object, person or place. These are: The perception of edges, the perception of spaces, the perception of angles and relationships, the perception of lights and shadows, and the perception of the Gestalt or whole - which, she states, comes from the previous four perceptual skills. She backs up her teaching methods with a cognitive argument stating that the left hemisphere of the brain deals with verbal analytical matters, while the right hemisphere deals with non-verbal spatial matters. She asserts that the right side of the brain 'works' for drawing, and that students should try to suppress activity of the left brain while they draw. The explanation is given in very simple terms, referring to the right side of the brain as the perceptual side, and the left as the analytical verbal side. For Edwards drawing involves turning off the left hemisphere, and allowing the right perceptual side of the brain to take over.

Her encounter in 1968 with psychobiological research (Sperry 1968) led to a hunch about what may be going on in the brain of the drawer, and an on-going curiosity about cognitive aspects of the act of drawing. As with Ruskin's innocent eye, Edwards' 'drawing brain' may not exactly match reality, insofar as existing in one specific cerebral location, but the concept serves a purpose for learning to draw. Despite wide spread scepticism about hemispheric differences current neuroscience is returning to a view more in keeping with Edwards' ideas about the functions of right and left brain (see Kandel 2012). While most scientists now warn against views claiming that the hemispheres may operate separately and control specific behaviours there is consensus that the hemispheres have distinct functions, co-operating in the execution of perceptual and cognitive processes. Broadly, based on its linguistic dominance, the left hemisphere is thought to operate in an analogue linear organising way, expert at fast processing and organisation of information into chronological 'stories' that make sense. From this view the implication is that the whole brain is crucial for observational drawing, with the hemispheres interacting in their roles, with the right perceiving the whole and the left constructing a story with lines around things and distinct parts standing out from the ground. Her idea of a cognitive shift raises the question of whether the hand needs to practise drawing at all, with the implication that the mapping from 3-d to 2-d, and from perception to action is a simple problem, solved by looking at things differently.

Know-how

Themes that emerge as practical 'keys' to drawing relate to procedural knowledge of how to approach the process i.e. drawing know-how, both implicit and explicit. Most theories of know-how focus on strategies of ocular visual attention rather than the hand, or eye hand coordination and communication. Ruskin's innocent eye is a form of attentional strategy, requiring the drawer to focus on particular visible qualities of objects and scenes. The innocent eye approach is also framed as 'forgetting about things', a way of looking and attending without thinking about declarative knowledge and memories relating to the thing to be drawn. A widely used instruction is to look at the 'negative space' around objects, rather than the object itself, as this is thought to facilitate the objective of forgetting / ignoring.
In an interdisciplinary study psychologist Kozbelt and philosopher Seeley (Kozbelt & Seeley 2008) argued that drawing practice gives artists 'perceptual advantage' in the form of know-how, with enhanced visual selection and discrimination skills. Notably, ways of looking are made explicit in pedagogy, and practitioners are often aware of specific strategies of looking. While most of these refer to visual capture and attention strategies, some recent scientific research explores eye and hand coordination, temporal aspects of the rhythm of drawing, the spatial rhythm of the gaze between original and the paper, the ratio between drawing and not drawing, and fixation durations (Tchalenko et al. 2003, Tchalenko 2007, Tchalenko & Miall 2009). This marks a move in research towards consideration of the 'know-how' of the drawing hand.

Ruskin, practice and physical knowledge

The important point about Ruskin is that he drew. This meant that he tested his theories in practice. Drawing for him is a matter of discernment, and finely-tuned decision-making and action. Contrary to received wisdom, he emphasised the role of the pencil and hand, and in his teaching he advocated an intelligent rather than an innocent eye. Ruskin's eye is highly sophisticated. He emphasizes '…it is quite necessary that you should draw it if you wish to understand the anatomy of the tree' (Ruskin 1858/1971 p.72). Ruskin's argument is more about the importance of specific forms of knowledge. He believed that physical practice and knowledge of physics and nature were both needed for accurate depiction. He teaches students procedural schema relating to materials and execution, and schema of optics and nature. He states that great men 'know the way things are going' (1971 p.91) and that there are occasions to know 'the reason of the appearance' (1971 p.54). He instructs students to search and seize for meaningful 'leading or governing lines' (1971 p.91) and a vital truth: 'I call it vital truth because these chief lines are always expressive of the past history and present action of the thing' (1971 p.91). In much of his writing he associates the physical engagement of drawing with an apprehension and understanding of the physical world. This concept foresees contemporary notions of enaction, where knowledge is acquired through engagement with the world rather than through passive learning of facts about the world. Drawing teacher Nicolaïdes (see 2008) talks of the same phenomena; knowledge acquired through action. Ruskin warns students to 'Beware of hand book knowledge.' (1971 p.76). The knowledge he values is found through individual practice; through movement. Ruskin's position is that finely-tuned observation is the key to drawing, and that drawing is a tool for discovery.

Ruskin's hand and pencil

Ruskin claimed that drawing alone can lead to an understanding of Leonardo or Titian, and stated that watercolourists '...must forever remain blind to the refinements of such men's penciling and the precision of their thinking.' (Lawrence Campbell in Ruskin 1858/1971 p.vii). The precise line that the sharp pencil produces affords the description of fine detail, such as a tiny indentation in a leaf. It also demands a rigour of execution, as any mismatch between the line seen and the line drawn, and any detail omitted, will be similarly evident. His notion that the pencil can sharpen the mind chimes with modern cognitive scientists such as Tversky (2011) and Kirsh (2011), who explore the roles of hand movements and drawing in thinking and cognition. Ruskin talks of the sharp pencil working over the object, pointing towards a role for the hand in perception, in clarifying the object. This implies a connection between the eye and hand, between the object and the drawing, between touch and vision. The notion suggests that touching the paper with the pencil is akin to touching the object. Indeed Nicolaïdes taught students to imagine that the pencil is touching the object itself (2008 p9). Psychologist Richard Gregory refers to vision as 'touch at a distance' (Gregory 1997 p.6) explaining that in evolution vision developed after touch, building from touch, and giving additional function and power, because organisms could begin to perceive from a distance. See section 2.7 below. Ruskin does not state exactly what he means by 'sharpened', or how the pencil may bring this about, whether through focusing attention, providing a specifc fine quality of feedback, or something related to vision as touch-like. However these views all point to the idea that the drawer practises or imagines the motor movement before drawing while assessing the object, both with the eye and hand. This also begs the question whether the rapidity of ocular vision is less suitable as a perceptual tool for observational drawing than the slower sense of touch, which may pick up details that the eye skips over.

> ...by working over the subject with so delicate a point, the attention may be directed to the most minute parts of it. Even the best artists need occasionally to study subjects with a pointed instrument, in order thus to discipline their attention; and a beginner must be content to do so for a considerable period. (Ruskin 1858/1971 pp.28–29)

Ruskin thinks that the pencil focuses attention. He talks of developing powers of judgment and of the manipulative power of drawing to develop appreciation of nature and art. The words 'judgment' and 'manipulation' emphasise cognitive assessment processes, and suggest that the eye and hand co-operate to hone these skills. Kirsh's review (Kirsh 2013) outlines scientific findings showing that tools have affordances (see Gibson 1979) that alter our ability to perceive, and that with practice we incorporate skills with tools into our sense of our bodily capacities.

Ruskin believed that the problem of novices is 'a marvellous and quaint confusion' (1972 p.73), which comes down mainly to a lack of know-how, but also to lack of understanding leading to a lack of ability to interpret impressions. Novices have 'access to some confused mode of execution' (1858/1971 p.70) and hence the key to drawing is to 'discover a mode of execution' and a 'trick of touch' (1858/1971 p.74). He instructs students to aim for slowness and control of hand and pen:

> The pen should, as it were, walk slowly over the ground, and you should be able at any moment to stop it, or to turn it in any other direction, like a well-managed horse.' (Ruskin 1858/1971 p.32)

The more one reads Ruskin the more one realises that he is talking about the importance of knowledge, and moreover the enactment of knowledge through drawing. He tells students about how trees grow, how foreshortening may confuse them, and about optical effects; reasons for appearance. When he says that a good draftsman will see 'action lines in everything...a good draughtsman will see under' (1971 p.96) he is talking about understanding what is behind the innocent eye, acknowledging that drawing is underpinned by complex schemas and enactive knowledge. Finally, demonstrating what would today be defined as an enactive view, and pointing towards Chapter 5 and 6 of the thesis, he urges you, the student, to 'carry out your knowledge' (1971 p.74).

Nicolaïdes – sensing, meaning and gesture

In contrast to drawing teachers such as Edwards, Nicolaïdes emphasised the limits of the eye as a perceptual agent, and believed that drawing needs to use all the senses, and experience. He wrote 'Drawing is the expression of the seen and otherwise sensed. Supplement vision with 'accumulated experience' (2008 p.6) and 'It has only to do with the act of correct observation, and by that I mean a physical contact with all sorts of objects through all the senses' (2008 p.18). He describes the purpose of his instructional book *The Natural Way to Draw* (2008 published in 1941 '...to have you arrive at the necessary relationship between thought and action.' (2008 p.1). He warns that the eye may mislead you, and suggests that students imagine touching the thing they are drawing. He proposes that students reason with the pencil: 'Listen to yourself think with the pencil' (2008 p.17). This poses questions for the thesis about the locus of thought and the orchestration of the body to allow thought and to allocate attention. Contrary to innocent eye approaches which try to minimise the influence of declarative knowledge, Nicolaïdes' focus is on meaning, rather than appearance. He would start a life drawing session with the instruction to appreciate the pose in terms of the feeling and human experience of the model. He states 'A man can usually draw best the thing he knows best...' (2008 p.6). This goes against much of observational drawing pedagogy, but this is the approach the thesis explores, to investigate alternative ways of drawing from life that do not require any negation of declarative knowledge, but rather allow meaning to underpin the process: 'Thinking more of meaning than the way the thing looks.' (2008 p.18).

For Nicolaïdes drawing is a research process. Like Ruskin he is clear that he is teaching students a way to learn about life and nature; '…they must acquire some real method of finding out facts for themselves' (2008 p.xii). He defines drawing as participation, and a sensitivity to 'impulses between object and you' (2008 p.17) and urges students to 'Spend much time making contact with actual objects' (2008 p.5). For Nicolaïdes seeing is driven by impulse, by a multi sensory perception of the situation. 'Groping, gradual understanding through practice' (2008 p.xiv). Here he is stating the proposition of the thesis, that practice builds towards greater understanding. Again like Ruskin, he believes that this understanding is of the laws of nature, not rules of drawing. The transformation of perception is brought about through practice, not by learning rules. He emphasises that one learns from 'doing' rather than thinking.

His instruction is to draw 'slowly, searchingly, sensitively' (2008 p.11) and he writes that 'A contour drawing is like climbing a mountain as contrasted with flying over it in an airplane' (2008 p.1). Progress is charted in 'increased knowledge with which you look at the world around you' (2008 p.2). Nicolaïdes emphasises the role of assessment processes, as well as the importance of making mistakes; ‘Test everything with all senses’ (2008 p.6).

Nicolaïdes suggests two methods of drawing, to enable the student to more deeply understand nature. The first is contour drawing, which entails keeping one’s eye on the object and not looking at the paper. He states that contour drawing functions ‘To couple senses of touch and sight’ (2008 p.9). His second method is ‘gesture drawing’, which he suggests as a way to explore the action of a pose. He instructs students ‘you should draw, not what the thing looks like, not even what it is, but what it is doing.’ (2008 p.15). This faster way of drawing is more concerned with engagement than with representation. At the heart of Nicolaïdes’ method is the belief that drawing is an embodied act. He instructs students to search for an understanding of a pose, what he describes as energy, and calls gesture: ‘To be able to see the gesture you must be able to feel it in your own body.’ (2008 p.15). He is not speaking of observation of movement, rather the discernment of a particular type of meaning contained in the pose and in the relationship between drawer and model / object / scene. The following section reviews how science is studying these issues of perception, vision, movement and drawing execution.

2.5 The science of observational drawing

(Readers please note that some psychological studies of enhanced perception in artists have already been outlined in section 2.3, and hence are not included here (see Kozbelt 2001, Chamberlain 2013).

Behavioural changes in eye and hand movements

There are three significant hypotheses in Tchalenko’s eye tracking research; that expert drawers segment the drawing process, spatially and temporally, that experts often draw ‘blind’ and that drawers encode visual information into motor plans for action (Tchalenko et al. 2014 in press). The latter hypothesis is particularly significant as it challenges long held beliefs about the way perception and drawing operate, under the assumption that we draw from visual memory; even when the object we are drawing is right under our nose. Tchalenko states of observational drawing that

> Not much is known about the process itself which, until now, was assumed to be invariably based on an ‘encoding to visual memory’ phase while the artist faced the model, and a ‘retrieval from memory and execution’ phase while the artist faced the paper. (Tchalenko 2009a p.791)

Until recently eye tracking research concentrated on how people view artworks rather than how they produce them. Yarbus’ early eye tracking tests were very influential because they identified that there were differences between eye paths for different cognitive tasks (see Yarbus 1967). Contemporary eye tracking studies of other skills search for active volitional (voluntary rather than automatic) eye movements related to specific tasks and skills, including driving (Land & Lee 1994), playing cricket (Land & McLeod 2000), sandwich-making (Hayhoe et al. 2003) and piano-playing (Land and Furneaux 1999). Now a small number of scientists have begun to eye-track subjects while drawing, and are building a picture of the drawing process in action. Dr John Tchalenko's tests have ranged from the copying of simple lines to drawing portraits from life and from moving video images. He found differences in eye movements between novice and expert drawers when copying complex lines, and over more than a decade of quantitative empirical research he has developed the three drawing hypotheses outlined. They observed that students and artists used very different strategies for copying, and that students were less accurate.

> ..the experts alone segmented the original drawing into simple line sections that were copied one at a time using a direct eye–hand strategy not requiring intermediary encoding to visual memory. (Tchalenko 2009a p.791)

From analysis of video footage psychologist Cohen concluded that experienced artists 'look little and often' at the original, or model, while inexperienced drawers adopt a variety of strategies, in general looking longer at the original (Cohen 2005 p.997). He assessed accuracy of drawings using a panel of human judges, and correlated accuracy ratings with patterns of eye movements. He found that more experienced drawers tended to look for shorter durations, often only a single fixation (in eye-tracking terminology 'shorter dwell time') at the model / original, and look back and forward between the paper and original more than novices. He found evidence of a distinct way of looking used by most of the more experienced drawers in his test group. Cohen's methodology was significantly different from Tchalenko's. He relied on human subjects to assess accuracy of drawings. Tchalenko avoided measurement of accuracy until his recent paper (Tchalenko et al. 2014 in press), preferring to concentrate on observation and recording of artists' drawing behaviour, to collect a range of data on several artists before beginning to define the 'expert drawer'.

This leads to the question of whether, and how, the hand and body play an active role in the transformation of artists' perception (described above in section 2.3). This is further explored below, in section 2.7, where the active nature of perception is explained.

Drawing movements - Motor processes

Execution of drawing is paid far less attention than the conceptual strategies outlined above.

For piano playing, students concentrate on learning motor processes and coordination. Although the skill is akin to drawing, in that it is specialist and demands 'other than everyday' ways of using the eye and hand, cognitive tricks are less evident in piano pedagogy. Several scientists have recently approached drawing as a physical skill. Philosopher Seeley and psychologist Kozbelt have highlighted the role of attention and motor encoding of visual information. From their review (2007), linking theoretical perspectives with supporting empirical evidence, they propose a model of drawing with a strong role for motor planning in visual attention and perception. They cite Cohen's finding (2005) that copying an upright versus an inverted face had no effect on the accuracy of non-artists' drawings. From this, despite the prevalence of 'innocent eye' techniques in drawing pedagogy, they suggest that these 'bottom-up' approaches may have limitations. They point out that visual sensory information is not always clear, and that we have to learn how to interpret it. This means that drawing can be seen as founded on a particular learnt way of interpreting the visual information, rather than on a way of limiting biases.

> ...the retinal input to the visual system is ambiguous and underdetermines its appropriate three-dimensional interpretation. This entails that successful perception depends upon prior knowledge encoded in the visual system that constrains possible interpretations of the sensory input. Thus, a purely bottom-up perceptual strategy like the one proposed by Fry (1919/1981) is just not computationally viable. (Kozbelt & Seeley 2007, p. 81)

See Gregory in Section 2.7 below, for more detail about visual ambiguities and the limitations of the visual system. Their thesis supports Gombrich's ideas of schemata of knowledge. Gombrich argued that artists seeking realism must engage in a hypothesis-testing process in which disparities between achieved depiction and their perception of the world are resolved. Artists, he suggests, test sets of marks against their perceptual experience and evaluate their practical success: in Gombrich's (1977) formulation, 'making comes before matching' (Gombrich 1977 p.116). Kozbelt argues that motor planning is important for gaze control and selection of salient features (Kozbelt and Seeley 2007 p.81), whereas Tchalenko concentrates on where people look in terms of synchronization with the hand's drawing action. Therefore Tchalenko attends to the hand while Kozbelt is interested in the eye and attentional strategies. Initially Van Sommers' research looked at mechanical aspects of drawing production. He considered the issue of what we know about objects from a physical rather than conceptual perspective; that our sense of the force of gravity determines our beliefs about how objects sit in space, and hence our 'top-down' assumptions about how they will look (1984 p.4). Van Sommers' statement about copying resonates with Merleau-Ponty's description of the artist's way of looking, and leaves room for models wherein the hand plays a significant role in a translation process:

> The fact is that copying, like imitation in language, is not a matter of item-by-item matching of perception to action, but a translation process, extracting relationships and using available skills to reconstruct them. (Van Sommers 1984 p.50)

How do the movements of the hand and eye conduct this translation? Tchalenko's research to date suggests that the key to successful observational drawing is knowledge of how to plan and execute the drawing. This entails knowing what to look for and how to capture it i.e. in what form to capture it. Tchalenko encapsulates the conventional versus new view, and the significance of their visuomotor hypothesis, in the following statements: 'Complex interactions of eye, head and hand movements punctuate this vision-to-motor transformation around which the cognitive process is structured.' (Tchalenko 2009a p791). Seeley and Kozbelt support the visuomotor encoding argument in their paper *Art, artists and perception: A model for premotor contributions to perceptual analysis and form recognition* (2008). Section 2.7 reviews Tchalenko and Miall's research in more detail.

Chamberlain (2013) explored the correlation between drawing experience and perceptual skills. In particular her empirical brain-scanning study, exploring the neural bases for drawing skills, revealed a '..neural focus on motor rather than perceptual areas, highlighting the importance of hand-eye coordination mechanisms and premotor planning in expert drawing.' (2013 p.51). Coen Cagli, Coraggio, Napoletano and Boccignone (2008) identify '…the "looped" influence between active vision and motor planning/control' (Coen Cagli et al. 2008 p.2) in observational drawing. Chamberlain states that '…it is highly likely that the interaction between fine motor movement and eye movements is a fundamental component of individual differences in drawing ability.' (2013 p.43).

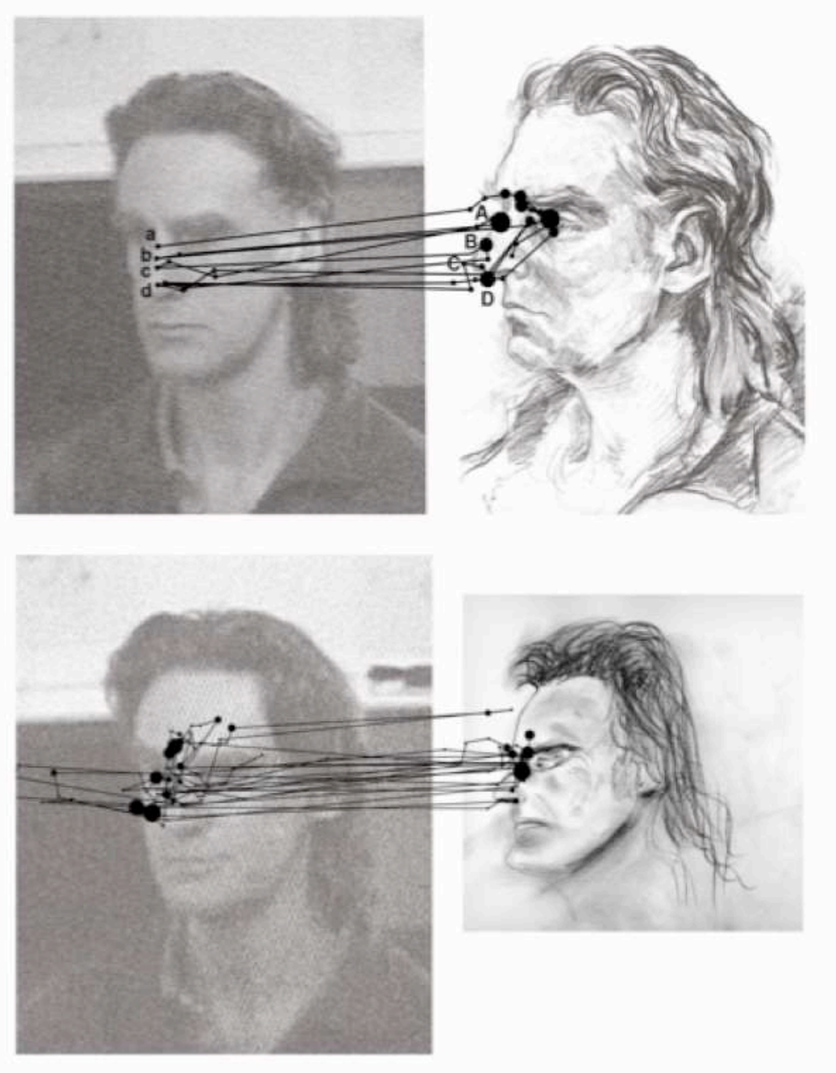
Role of memory

The role of memory is also a key question in drawing research. Many artists and teachers hold the view that visual memory is required to 'capture' the image from the world and transfer it onto paper.

Nicolaïdes states that

> With the exception of the contour study, there is no drawing that is not a memory drawing because, no matter how slight the interval is from the time you look at the model until you look at your drawing or painting, you are memorizing what you have just seen. (Nicolaïdes 2008 p.40)

This view of the role of memory is pervasive, under the assumption that the drawer must



Expert's drawing

Beginner's drawing

Fig. 2.1 Eye movements during drawing of model's nose - A, B, C and D are segments drawn by expert following fixations a, b, c and d (durations 0.40–0.880 s). (from Tchalenko 2009a, fig. 9, p.798).

look away from the original in order to draw on the paper, and hence rely on visual memory. However scientists have recently begun to challenge this view, by questioning how visual sensation is encoded, and the role of motor planning in the execution of drawing: Tchalenko's visuo-motor hypothesis proposes that

> …each detail to be drawn is not retained as a visual memory, subsequently transformed to a drawing action, but is retained as an intended drawing action. (Tchalenko et al. 2014 in press p.4)

The challenge he raises is against the traditional view that drawing entails the capture of visual images with the eye. His data offers the new view that motor planning plays a role in the production of drawing; in preparation for drawing a line you plan / imagine the hand movement you will make, i.e. the action of drawing, as distinct from simply capturing some sort of static visual image in your memory. This theory is based on Miall and Tchalenko's groundbreaking finding that motor areas of the cortex are activated during encoding phases of drawing.

Chamberlain also found neuropsychological evidence to suggest that visual imagery is not necessary for representational drawing, citing a patient researched by Botez et al. (1985), who despite a severe visual imagery deficit was still able to produce detailed drawings from observation, but not from memory. 'This suggests a dichotomy in the role of visual imagery for online drawing versus drawing from memory.' (Chamberlain 2013 p.38). Calabrese and Marucci (2006) found that there were no differences between artists and non-artists in self-reports of experience of visual imagery, suggesting that visual imagery may not be a required skill of observational drawers. Chamberlain writes that

> Despite a putative overlap between visual perceptual and visual imagery processes, it appears that there is little evidence yet for a link between imaging capacity and drawing ability.' (Chamberlain 2013 p.38)

Tchalenko and Miall's most recent research (Tchalenko et al. 2014 in press) on 'blind' drawing, where the drawer does not look at the paper, explores drawing methods that do not require short term visual memory, and challenges their original assumption that drawing is carried out while looking at the paper rather than the original.

Blind drawing – keeping your eye on the subject

Tchalenko used the term 'blind drawing' to refer to drawing conducted while the eye is on the original rather than the paper. He identified this method in several experts (see especially Tchalenko et al. 2014 in press). In pedagogy 'blind contour drawing' is a widely used method, but it is generally proposed as a warm-up exercise, and as another cognitive trick to enable drawing; Betty Edwards advises students that this takes the 'judgemental left brain' out of the picture, as the eye is not looking at the drawing and therefore cannot judge it. Nicolaïdes' point of view is close to many contemporary drawing practitioners (see Lyons 2009) believing that blind drawing allows the drawer to attend to the subject and to connect with it in a particular way. Tchalenko's findings suggest that experienced drawers do in fact use a large proportion of blind drawing as part of their method, and the more so, the more complex the image they are drawing (Tchalenko et al. 2014 in press).

The next three sections examine in more depth Tchalenko's findings (section 2.6) and then vision and perception theory (sections 2.7 and 2.8) in order to create a platform to explore how drawing practice may develop new ways of perceiving and exploring the world.

2.6 Motor not photo

Differences in eye movements between expert and novice drawers

Tchalenko and Miall's research began with Tchalenko's two observational studies of the eye and hand movements of the artist Humphrey Ocean (Tchalenko 1991 & 2001). From 2000 on, his collaboration with Miall has produced a series of quantitative behavioural studies of novice and expert drawers, using eye-tracking technology, including a study using simple drawing tests and complex portrait drawing tests (Tchalenko et al. 2003). Their data suggest that highly experienced drawers share some characteristics rarely found in less experienced drawers, notably rhythmic patterns of eye movements between model and drawing, targeted fixations and more segmentation of the drawing into short lines.

They made a detailed case study of Humphrey Ocean's observable behaviour during eleven and a half minutes of making a pencil drawing (Miall and Tchalenko 2001). This was the first study that timed the eye movements of an artist, using an eyetracker; one other researcher had timed a painter's eye movements using video (Konecni (1991). The methodological decision to observe movements of drawing led immediately to interesting results, suggesting that Ocean's way of looking during drawing was different from his everyday looking. His eye fixations when drawing were of twice the duration of his everyday fixations. They characterised his eye movements as 'targeted' (2001 p.38), describing Ocean's systematic analysis of the model's face as involving a sequence of single fixations on selected details of the model's face (2001 p.38). They wrote that

> In contrast, untrained subjects did not show clear changes in eye movement

> when drawing; nor did they show precise fixation on individual details of the model. (Miall and Tchalenko 2001 p.38)

The main findings of interest up to this point were Ocean's double length fixations and a more regular rhythm of eye hand coordination. They found that some methods are used regardless of drawing experience, and that novices are as accurate as experts at copying a simple segment of line without looking at the paper while they draw. Their findings suggested that, like Ocean, experts have more targeted eye fixations. Fig 2 1 shows this distinction between novice and expert, with the lines representing the gaze path between model and paper, and the black dots representing fixation positions.

> All subjects with some experience in drawing....showed stable single fixations on the detail of the model that they were drawing. This feature was especially marked with HO: a saccade originating on the paper would find its target after one or two adjustment saccades and then lock onto the point for the duration of the fixation, i.e. one second or more. (Tchalenko et al. 2003 p.709)

Blind drawing suggests encoding into motor rather than visual memory

As outlined above (in section 2.5), analysis of eye-tracking data over several studies led Tchalenko to question the role of visual memory in the drawing process. His findings on 'blind drawing' show that drawing can be carried out by making a visuomotor connection between the eye and hand, without needing to look at the paper, the pencil and the line as it is produced. This implies that the object being drawn need not necessarily be recalled as a visual memory or even committed to visual memory. They tested hypotheses about segmentation and visuomotor encoding in relation to data from a more complex drawing task, the copying of a life drawing by Gaudier Brezhka, drawn by novices, intermediates and experts (Tchalenko 2009). At this stage 'blind drawing' was imposed on subjects as one of the experimental conditions. In later research they return to a more naturalistic observation and find that several experts use 'blind drawing'.

They outline the accepted view of observational drawing, and then suggest an alternative radical new view, based on their findings:

> The basic assumption implicit in the studies of drawing from life mentioned above is that some form of working memory is involved in the drawing process..... This conventional interpretation posits the following sequence: the original, or part thereof, is first encoded to visual memory during fixation on the original, after which the subject turns to the paper and drawing proceeds from the stored mental image. As the image fades there comes a point where the subject needs to return to the original. (Tchalenko and Miall 2009 p.369)

They found that this model does not always hold. In particular they observed phases of 'blind drawing', with only short glances to the paper at the beginning and end of a line segment. This led them to ask whether, because the hand was operating alone, drawing of the line was controlled by motor memory rather than visual memory

> It seemed as if the shape of the line itself was "known" to the hand, and that the eye's role was restricted to ensuring that the line started at A and ended at B, i.e., a role of spatial positioning.' (Tchalenko and Miall 2009 pp.369-70)

They stated that simple shapes, such as an S, can be accurately drawn without the eye seeing the paper or the hand, but that scale, proportion and orientation of lines require sight of the paper as the line is being drawn. (2009 p.370). This remains Tchalenko's position. He concludes that these results suggest a way of drawing governed by this alternative eye–hand interaction:

> In other words the visual information captured from the original is transformed into a motor programme that can be executed instantly, online, rather than retained as a mental image to be executed later after the subject has turned to the paper. (Tchalenko and Miall 2009 p.370)

This conclusion relates to contemporary eye tracking research of everyday visually guided tasks, such as driving and sandwich-making. Hayhoe and Ballard (Droll & Hayhoe, 2007, Hayhoe & Ballard, 2005, Ballard et al. 2003, Hayhoe et al. 1998, Land 2006) define this direct transformation as a 'just in time' strategy, without intermediary encoding to an internal representation in the brain. These strategies are thought to minimise the use of working memory, by gathering perceptual information just in time. In the case of drawing this is achieved by looking back and forth between object and paper more. Cohen found this increased gaze frequency to be a marker of drawing expertise (2005).

Chamberlain found, from her review of literature and her own empirical research, that:

> There is sparse evidence of a connection between visual short-term memory (VSTM) fidelity or capacity and drawing ability, and as a result it has been argued that premotor plans may circumvent the need to rely on short-term representations. This line of argument highlights the role of an interactive visuomotor system in drawing. (Chamberlain 2013 p.42)

Indeed, from their finding that subjects were spending time drawing while they were looking at the original, Tchalenko and Miall concluded:

> The fact that visual perception of the original and motor execution of the copy occurred simultaneously suggests that drawing proceeded from a visuomotor mapping of the original and not from an encoded image of the original. (Tchalenko and Miall 2009 p.373)

Their point is one about timing and memory, proposing that in this case the encoding to motor action takes place during the looking, rather than later, during the drawing. Miall's brain-imaging supported their drawing hypothesis, finding activation patterns 'consistent with visuomotor mapping during the encoding phase, and no evidence for retention and recall of a mental visual image was found.' (Tchalenko & Miall 2009 p.376). In summary they stated that they found

> Instances when the conventional interpretation of a visuomotor transformation applied to an encoded visual mental image did not adequately describe drawing from life... (Tchalenko and Miall 2009 p.375)

Functional imaging study of the cognitive neuroscience of drawing

Next they advanced their study of 'blind drawing' from memory, and from life, by using fMRI brain scanning (Miall, Gowen & Tchalenko 2009). In line with other eye tracking research, they examined drawing as a universal skill, on the rationale that 'In most people it is a stable long-maintained skill, with little or no active learning component, because we typically learn to draw during childhood and rarely try to improve in later life.' (Miall, Gowen & Tchalenko 2009 p.394). They tested thirteen untrained participants. This study therefore offers details of a general model, much of which may apply to experts as well as less experienced drawers. In pursuit of cognitive correlates of drawing Miall and Gowen devised tests that separated drawing into distinct phases - visual encoding, memory, and execution – and recorded the functional activity in the brain during each step (Miall, Gowen & Tchalenko 2009 p.395). For visual encoding (i.e. without any drawing) they found that subjects 'capture' information through patterns of gaze fixations different from those used to identify the face. They suggest that a spatial representation of the face is stored, ready for drawing execution. At this stage the fMRI data could not unambiguously identify where this representation may be stored, apart from 'a further hint that the premotor cortex is a possible site of retention as a motor plan' (Miall, Gowen & Tchalenko 2009 p.405). They suggest that:

> Subsequently, the drawing process recreates these planned actions as the eye and hand are guided by the retained visuo-motor information and the drawing proceeds under executive control from higher frontal areas...' (Miall, Gowen & Tchalenko 2009 p.405)

When drawing from memory, subjects' brain activity supported the visuomotor hypothesis:

> Drawing from memory activates areas in posterior parietal cortex and frontal areas. This activity is consistent with the encoding and retention of the spatial information about the face to be drawn as a visuo-motor action plan,...' (Miall, Gowen & Tchalenko 2009 p.394)

Themes and variations - Matisse drawing. An eye-hand interaction study based on archival film

With this study Tchalenko (2009b) returned to observational methods of the kind employed in his first study of Ocean, analysing film footage of an artist drawing. In addition to quantitative data about the eye and hand, he offers a cognitive interpretation of the changing patterns of eye hand interaction, using Matisse's own reflections on the process. Tchalenko's detailed analysis of Matisse's method leads to new questions about the act of drawing. He found that Matisse, like Ocean, has a steady rhythmic eye movement cycle between model and paper, and makes single fixations on the model. However the initial suggestion that artists may use longer than usual fixations on the model was not supported by analysis of Matisse's eye movements. His fixations are much shorter and of comparable length to those used in everyday looking (approximately 1/3s). His method closely relates to that of subjects copying line drawings (see Miall, Gowen & Tchalenko 2009 and Tchalenko 2009b). Both cases suggest that a visuomotor encoding process governed the transformation into a picture, without recourse to sequential visual details held in working memory.

Through observing Matisse's method, which included 'blind drawing', Tchalenko develops his argument. He states that drawing while looking away from the hand and paper '…has never been recorded as the governing strategy when drawing from life.'(2009b p.437). This marks a significant moment in his research, and suggests that blind drawing may be central to observational drawing practice, beyond just as warm-up exercises, as proposed by both Nicolaïdes, and Edwards.

Matisse's drawing was of two different types, with "themes" being observational studies, a way of learning and observing the model, and "variations" being more akin to musical performances, in that the lines were drawn swiftly and in phrases, such as the line of the upper lip. His process of making studies and then drawing a series of variations raises interesting questions about distinctions between observational drawing and drawing from memory and imagination. It is unclear whether Matisse's variations are more akin to drawing from memory than from life, and hence hard to interpret his eye movements within the parameters of observational drawing. In Tchalenko's most recent study he discovered that Rodin similarly drew blind, and in his case in a much more clearly observational way (see Tchalenko et al. 2014 in press).

Segmentation

In the study *Segmentation and accuracy in copying and drawing: – Experts and beginners* (Tchalenko

2009a) Tchalenko tested the Tchalenko-Miall drawing hypotheses in the condition of 'drawing from life', with sixteen subjects, ranging from expert to novice. He concluded that the study suggests that segmentation 'forms part of a fundamental eye–hand strategy leading to accuracy in copying and drawing.' (Tchalenko 2009a p.792). He specified that the cognitive aspects he studied were the selection of lines to draw, followed by drawing of the lines (Tchalenko 2009a p.791). He restricts his model to these aspects, without elements of assessment, feedback, or trial and error processes. Tchalenko combines hypotheses about segmentation and blind drawing, and proposes that this is a 'no-memory strategy', with the original divided into simple lines and immediately drawn. He states that 'In this way the use of working memory was minimized or even completely avoided.' (Tchalenko 2009a p.799). He interprets this in relation to recent eye tracking studies (see Ballard et al. 1995, Droll & Hayhoe 2007) and cognitive theory about memory load and 'just in time' strategies:

> Such a "just in time" strategy was a deliberate choice by the expert who could have stored in memory and drawn a second segment in continuity with the first, but chose instead to refer back to the original with a new gaze shift cycle. The cost of extra eye and head movements was preferred to the high memory loads presumably required for accurate copying of shape and detail. (Tchalenko 2009a p.799)

In this paper Tchalenko suggests how his findings may contribute to pedagogy, stating that the beginners' perception was 'not appropriate' for drawing.

> Concentrating on segmentation may be thought of as a well-defined abstract task, less likely to divert the beginner into trying to draw what a nose is supposed to look like rather than the geometrical shape out there in the external world. (Tchalenko 2009a p.799)

He found that beginners did not subdivide the image into simple lines. He surmised that training and experience had taught experts to segment.

Tchalenko et al. continued the study of 'blind drawing' (Tchalenko et al. 2014 in press) by testing thirty subjects, with little to moderate drawing experience, on several drawing tasks ranging in complexity. They found that the amount of blind drawing increased progressively as tasks became more complicated. Their model becomes more fine-grained, with details of exactly when, during the production of a line segment, subjects look at the paper – just before the end of a phase of drawing (Tchalenko et al. 2014 in press p.12) and

> Each line segment was encoded with the help of one or several fixations on the original stimulus. Simultaneously, the hand started drawing the segment on the picture while the eye was still centred on the original. (Tchalenko et al. 2014 in press p.17)

They report that between 43% and 62% of time spent drawing was blind drawing. They suggest that the more complex tasks required more visual analysis of the original; what could be referred to as finding or choosing the lines.

> We suggest therefore that, under the test conditions used in the present investigation, our results show that the amount of blind drawing was positively related to task difficulty: the more difficult the task of determining the line segment to be drawn, the greater the amount of time required for visuomotor encoding during gazes on the original. (Tchalenko et al. 2014 in press p.18)

They connect this behaviour with O'Regan's suggestion that we can use the external world rather than memory for information (O'Regan 1992). He argued that when an object is visible it does not need to be committed to memory, as it can be referred to as often as needed, to inform action. (Tchalenko et al 2014 in press p.19). Furthermore this idea of refreshing of memory fits with Cohen's findings (2005), correlating high number of gaze shifts with accuracy, as well as suggesting a solution to the problem of 'conceptual bias':

> ... the high frequency of original gazes replaces drawing from an image held in memory by drawing directly from the perceived stimulus. This, in turn, avoids ineffective and distorting strategies such as, for example, assimilating the to-be-drawn stimulus with prior knowledge of a prototype. (Tchalenko et al 2014 in press p.21)

Tchalenko makes a significant contribution to drawing research by bringing attention to bodily movement and coordination. Previous research focused on psychological aspects of drawing production and, as outlined, on the role of looking. He brings the focus to the motor system controlling the hand. As hoped, his attempts to isolate phases of the drawing process offered useful information about cognitive processes, and a challenge to the conventional view of visual capture.

However he models drawing as a linear sequence, never escaping from the computational paradigm wherein the eye captures the image and the hand then executes the drawing. He is reductionist in approach, creating a simplified model of the observational drawing process, that can be described in a chronological narrative.

2.7 Active vision theory - Richard Gregory

Vision as hypothesis testing

Another scientist, Richard Gregory, brings artists' accounts and views into a contemporary scientific context. In *Eye and Brain* (Gregory 1997) he outlines the physiology of the eye and relates it to everyday functioning of the eye, and in *The Artful Eye* (Gregory 1995) he distinguishes between 'sight-for-survival' and adapted sight for 'seeing and creating beauty' (1995 p.v).

Gregory explains vision as contingent, operating via a system of hypothesis testing. We interpret sensation from a position of what might be the case, i.e. we bring knowledge of physics to every encounter. This includes knowledge of how gravity affects objects, how light falls on things and the fact that things appear smaller when they are further away. He comments that 'It takes a leap of imagination to appreciate that the eyes set extremely difficult problems for the brain to solve for seeing to be possible' (Gregory 1997 p.1).

Vision is sketchy and underdetermined

Gregory describes ocular vision as 'sketchy' (1997 p.2). How do observational drawers augment this sketchy view into a detailed accurate presentation? This is a central question emerging from this interdisciplinary review. He asks how ocular vision works: 'How are ghostly images transformed into appearance of solid objects, lying in an outer world of space and time? (1997 p.1), when 'All the brain receives are minute electrochemical pulses of various frequencies, as signals from the senses. The signals must be read by rules and knowledge to make sense.' (1997 p.2). Gregory's view implicitly opposes innocent eye theories, making clear that any active vision theory entails a large contribution from the brain, and from top down processes. More than half of the cortex is involved in vision, with many 'top down' pathways contributing to perception. He comments 'What is striking is the huge amount of brain contributing to vision, giving immense added value to the images of the eyes.' (1997 p.2) and 'The added value must come from dynamic brain processes, employing knowledge stored from the past, to see the present and predict the immediate future.' (1997 p.2). He emphasises the importance of prediction for survival. The eye is fast, its main function being to assess danger and to inform action.

Perception is interpretation

Gregory outlines the dominant view in cognitive science, that the brain stores representations in various forms that are already interpretations of sense data. He states that the crucial point is that '..sensory signals are not adequate for direct or certain perceptions; so intelligent guessing is needed for seeing objects.' (1997 p.5) and '...perceptions are predictive, never entirely certain, hypotheses of what may be out there' (1997 p.5).

An important element of Gregory's view is the role of touch. He explains that 'The brain's task is not to see retinal images, but to relate signals from the eyes to objects of the external world, as essentially known by touch. Exploratory touch is very important for vision.' (1997 p.6). He states that: 'Seeing objects involves general rules, and knowledge of objects from previous experience, derived largely from hands-on exploration.' (1997 p.11).

There is much research evidence that the hand dispels illusions, and can augment visual perception (for example, see Aglioti, DeSouza, & Goodale 1995 and Ganel, Tanzer, & Goodale 2008). Chamberlain concludes from her review of research findings: 'Thus it would seem more likely that the hand would express a less biased impression of the world than the eye.' (2013 p.44). See Chapter 5 for details of perception research.

2.8 Enactive perception theory - Alva Noë

When Alva Noë states that a 'picture is composed of movements' (Noë 2004 p.40) he reminds us that a drawing is a process, and both records and evokes action. His proposition is that perception is an activity rather than an internal representation of the world. This moves away from a passive view of the eye that holds that the eye receives information when light falls on the retina. Active vision (see Findlay and Gilchrist 2003) defined the process as the 'capture' of visual information, emphasising the role of attention and eye movements in perception. The new scientific view (see Tchalenko et al. 2014 in press) is that motor planning plays a greater role than previously thought in drawing from life. The enactive argument takes a further step, by accounting for feedback processes and distributed cognition. Observational drawing is a particular way of moving, developed through practice, and hence a particular system for collecting sensory information, for development and learning.

Perception in action

'Perceiving is a way of acting' and 'not something that happens to us, or in us. It is something we do' (Noë 2004 p.1).

Our relationships with objects alter as we move through the world. We learn from our experiences, and this knowledge informs every subsequent encounter; how we approach objects, and our sensory engagement and understanding. Every time we perceive something a shift occurs that is only possible through movement. Moving changes our perspective and perception. The most reduced form of this is when we move only our eyes, and keep the rest of our body still. Our visual answers are those that make the best sense of things from our current point of view, rather than visual absolutes: 'The world makes itself available to the perceiver through physical movement and interaction' (Noë 2004 p1).

In the mid-twentieth century Merleau-Ponty developed this enactive view of perception as an embodied experience (see *Phenomenology of Perception* 2002). The discipline of cognitive science was born at the time Merleau-Ponty was writing his philosophical treatise, and his essays *Eye and Mind* (1964a), *The Visible and the Invisible* (1964b) and *Cezanne's Doubt* (1964c). He related his insights about phenomenological experience of visual perception to experimental findings. In *Cezanne's Doubt* he considers the artist's efforts to represent his perception of the external world in the light of the science of vision. Merleau-Ponty's position, based on phenomenological experience, is that we ourselves create boundaries and lines between things, as part of the process of living and giving meaning to our lives;

> For the world is a mass without gaps, a system of colours across which the receding perspective, the outlines, angles and curves are inscribed like lines of force: the spatial structure vibrates as it is formed. (Merleau Ponty 1964c p.15)

In a similar vein Gallese argues that binary accounts leave many questions unanswered in science, including the division between sense and action:

> Today we are constantly exposed to the so popular mantric succession of dichotomies proposed as the state-of-the-art account of vision: where/what, how/what, pragmatic/semantic, egocentric/allocentric, and so on.(Gallese 2000 p.25)

To advance in our understanding of perceptual learning we need to entertain and grapple with not only feedback processes but with these couplings and interplays between brain processes. According to the above, drawing and perception both classify and delineate experience, to make sense of impressions and enable us to learn and act. Objects offer affordances, opportunities for action (see Gibson 1979). Gallese suggests that

> ...objects are not merely identified and recognized by virtue of their physical 'appearance', but in relation to the effects of the interaction with an agent. In such a context, the object acquires a meaningful value by means of its dynamic relation with the agent of this relation. (Gallese 2000 p.31)

McGuirk articulates the embodied view of cognition in relation to drawing:

> By ceasing to be a mere observer and, through the process of feedback, the draftsman/woman in a holistic sense becomes a part of an interaction. In the 'situated cognition' view, the person/environment relationship is radically altered from the Cartesian epistemological model's emphasis on the separation of subject and object, to one of a holistic integration. (McGuirk 2011 p.7)

Perceptual development and learning

As explained above Richard Gregory describes visual perception as hypothesis testing, wherein we develop blueprints, or schemas, of how we expect things to look and behave.

We test our sensory experiences against these (and see Gombrich 1977). If something we see does not fit, in terms of our experience, for example appears to defy gravity, moves in a strange way, casts strange shadows, we will step back, reassess and try to understand it within our framework of what we consider to be physically possible. This means that in most cases what we sense is interpreted within a framework of what we expect to see. These frameworks consist of tacit knowledge as well as declarative knowledge.

Perceivers have an implicit, practical understanding of the way movements produce changes in sensory stimulation. They also have an implicit practical understanding that they are coupled to the world in such a way that movements produce sensory change (Noë 2004 p.66).

In seminal research Held and Hein explored perceptual learning and how it stems from self-motivated action (Held & Hein 1963). They found that kittens who were allowed to control their own action developed better depth perception than those who were passively moved around. They found that kitten A, who was moved around in a sling in a carousel, did not develop depth perception as well as kitten B who was controlling its own movement. This suggested that perceptual learning relies on self-directed action and on establishing links between volitional movement and sensory experience.

Perception needs a body

Contrary to 20th century behaviourist views, wherein the physical stimulated the mind and the mind then controlled action, James Gibson suggested that the mental and the physical were intertwined. He thought that learning progressed in parallel, with the mind and body acting together, finding physical and cognitive meaning. The important point is that perception is active, and that no sense is simply a passive receiver of stimuli. Although there is debate about schemata and internal representations in the brain, Gregory's idea of vision as hypothesis testing is in line with Gibson's view that perception is an active exploratory activity, searching for information (Gibson 1979).

The argument for enactive vision takes various forms; situated and distributed cognition, and embodiment theory. The latter argues that thought is intertwined with the body (see Lakoff and Johnson 1999.)

Johnson emphasises that schemata are dynamic and embodied, providing exploratory and organising structures, allowing the body to think as well as perform (Johnson 1987). O'Regan and Noë also consider perception to be exploration, as follows:

> Instead of assuming that vision consists in the creation of an internal representation of the outside world whose activation somehow generates

> visual experience, we propose to treat vision as an exploratory activity. [. . .] The central idea of our new approach is that vision is a mode of exploration of the world… (O'Regan & Noë 2001 p.940)

When conceived as a mode of exploration the distinctions between eye and hand begin to break down, firstly allowing us to recognize that both are motor agents, with the power to focus attention, and to explore.

2.9 Methodologies in contemporary drawing research

How is accurate drawing achieved?

A common approach for drawing research, both historically and currently, and in science and pedagogy, is to try to find out how accurate observational drawing is achieved. The researchers fall into two categories, those for whom answering this question is valuable for its contribution to pedagogy, and those wishing to shed light on cognitive and perceptual processes.

Ruskin was offering practical advice, and perhaps the notion of the innocent eye worked, and still works, as a useful conceptual strategy for drawing from life. Edwards' drawing advice and the cognitive model she offers her students raise the same issue, one central to this study and methodology; how scientific facts and evidence about drawing production sit with the pragmatics of drawing education. An objective of this review and the following chapter on methodology is to explore how science and reflective practice may offer new - both useful and empirical - knowledge for the drawing studio and educator.

Research foci divide into the study of physically observable motor elements of drawing (the eye, the hand, and eye hand interaction) and the study of non-observable aspects of cognition and perception. Situated and embodied perspectives on learning and cognition emphasise the epistemic difficulties with separating behaviour from cognition and action from perception.

In experimental conditions Cohen and Bennett (1997) attempted to separate elements of drawing into motor coordination, the decision-making process, misperception of one's drawing, misperception of the subject / thing to be drawn. They wanted to identify factors that prevent accurate observational drawing, and, as outlined above, they concluded that 'misperception' of the thing to be drawn is the sole cause of inaccuracy. There is an underlying concern about whether cognitive aspects of the drawing task can be split into these elements by experimental procedure. This needs to be born in mind in any experimental set-up where the drive is to isolate and control elements to create testable scenarios.

Observation of behaviour

Van Sommers' seems to refute Cohen and Bennet's claim, finding 'executive constraints in drawing' (1984 pp.1-29) i.e. problems relating to the drawing action by the hand, and their influence on accuracy. Van Sommers began with observation and collection of data from a large number of subjects over many years before interpreting it. His method is more relevant to this study than his findings, as he did not distinguish experts from novices, so does not offer an expert model of drawing execution. However he correlates drawing strategies and sequences of execution with accuracy, presenting more and less successful approaches.

Van Sommers combined scientific testing with observation, exploring the 'principles of simple drawing' (1984 p.3). In the early 70s, he began by looking for 'executive consistencies in drawing' (1984 p.3) i.e. common drawing procedure in terms of the motor execution, e.g. when people draw the lines in the same order.

His study offers quantitative data about drawing production by numerous untrained drawers, providing base data about common strategies and behaviours and suggesting why some tasks are found to be easier than others. His early naturalistic research provides detailed and extensive information about process. Van Sommers studied untrained drawers, both adults and children, describing their efforts as 'vernacular' (1984 p.xii), so his emphasis was on defining general drawing approaches.

He defines his study as '...basically empirical rather than theoretical or speculative' (1984 p.xi) and states that 'It is based on the documentation not only of products, but of processes of production' (1984 p.xi). His research programme consisted of observations and analysis, recording drawing and copying performances on videotape. Of this early method he states: 'I found it expedient to include a good deal of copying at this early stage, since that provides relatively homogeneous output from which consistencies can be extracted.' (Van Sommers 1984 p.3).

Similarly in the early stages of his research Tchalenko focused on how subjects copy lines: Copying is a good way to limit variables without having to create unnatural experimental conditions. Thanks to the recent technological advances in eye-trackers (see Hayhoe & Ballard 2005 and Ballard, Hayhoe & Peltz 1995), we have the opportunity to extend his method to include analysis of eye movements and patterns of looking. These technological developments are increasing the scope of eye movement investigation in real-life situations. Coupled with an increasing interest from cognitive science in qualitative findings and experiential approaches (see Varela et al. 1993) there is great potential for a deeper understanding of the drawing process.

As already outlined, there is a consistent emphasis on the importance of looking, for accurate observational drawing. Hence the obvious way to try to understand what may be behind these drawing instructions and drawing hypotheses is to look at artists' eyes. The eye is part of the brain, open to observation in natural settings. Furthermore observational drawing provides visible output in the form of the process and the final drawing, which can be quantitatively analysed. On these grounds Tchalenko began his research project to explore eye movements in close detail using eye-tracker technology. Tchalenko's scientific approach represents a shift in drawing research, taking it out of the psychological and creative arena into a behavioural experimental framework, where drawing is explored as a physical task, and attention paid to eye-hand interaction. This connects with research in other eye tracking studies where models of active, task-specific vision are being built (Hayhoe 2000, Land and Hayhoe 2001, Land 2006), for example for driving (Land & Lee 1994), cricket batting (Land & McLeod 2000) and sandwich making (Ballard et al. 1992) and also, in Land's case, an eye tracking study of sketching (see Land 2006, Land & Tatler 2009 pp. 75 -82).

The progressive step Tchalenko made was through his insight and decision to consider the movements of drawing, rather than perception for drawing. However this step also limited his exploration by framing drawing as a perception to action skill, wherein the eye does the looking, and the hand the execution.

2.10 Summary, conclusions and how this review informs my thesis to follow

The review concludes that looking at things with the eye is just part of the picture. The Cartesian split between mind and body and historic reasons for prioritising the intelligence of the eye over the hand have led to a cognitive ocular-centric perspective on observational drawing. My thesis goes on to explore eye-hand interaction and to question the location and character of perception for drawing. The review also set out recent scientific findings on the movements of drawing, and outlined active and enactive perception theory, to enable consideration of how these may together contribute to observational drawing practice and pedagogy. My thesis questions how cognition is, and might be, enacted in behaviour, and how theory contributes to practice. In practical terms the review led to decisions about how to proceed, and established a foundation for development of my thesis. What emerged was a case for exploration of temporal and spatial elements of the orchestration of eye and hand, from a more dynamic embodied view.

The impetus for the study from hereon was to explore the temporal relationship between vision and drawing, and draw parallels between the two activities, to establish the argument that drawing is not a perception to action task, but rather a perceptual process in itself, a way to process and understand sensory information and our world. The existence of what Gregory terms 'adapted sight' is central to the thesis, suggesting that we need to look beyond the eye and mind to the body and the hand for answers to the development of this especial vision, and for a more complete view of drawing. Gregory's description of visual perception as imaginative (Gregory 1997 p.1) and a reasoning process, aptly describes drawing; using imagination to solve the problems the eyes set. This postulates that if the eyes do not provide enough information for drawing, then how is more information gathered? Does the hand help to gather more perceptual information? The study asks how the hand contributes to perception, whether by using haptic senses, by motor planning and encoding ocular information into executive information for the hand, or by proprioceptive coordination of the eye and hand. That vision is fast and drawing is often slow is a key consideration for the thesis, explored in the quantitative strand and the drawing method developed.

Key positions that the review helped to establish were that:

Drawing pedagogy largely adheres to the view that the key to observational drawing lies in the eye and knowing how to look at things.

It is worth examining how we move when we draw, rather than thinking only about how we look at things.

While science does consider movements of drawing, a limitation is that it currently frames the drawing process as a perception to action task.

Researchers and drawing practitioners would do well to question the dichotomy between cognition and action and to explore them together by attending to non-propositional procedural knowledge and to 'bodily thinking'.

Particular points were considered worth pursuing in more depth in the thesis, with potential to offer insight into perceptual processes involved in observational drawing.

1) Ruskin's notion that the pencil sharpens perception

2) Gregory's point that vision is underdetermined, and hence that the eyes set problems for the brain and body

3) Tchalenko and Miall's visuo-motor hypothesis, and the proposition that drawing proceeds from a motor plan rather than a visual mental image

4) Noë's proposition that perception is located in bodily action, rather than in the eye and brain

The review brought to light notable gaps in drawing research, such as the lack of longitudinal studies of the learning process or consideration of the role of the hand, beyond that of executing the eye's plan. Section 2.5 showed that existing teaching paradigms focus on the eye and 'learning to look', and lack consideration of physical movements. This contributed to my decision to focus my thesis on observable behavioural elements, looking at drawing as an embodied activity, and exploring the execution and meaning of movement. Chapter 3 builds on review section 2.9 to outline the methodology used in my thesis, explaining its development from the work of Tchalenko (who was my mentor during the initiation of the thesis) and how it combines elements from experimental research with experiential and reflective practices and methods.

Furthermore I planned to observe changes that come about through practice to see if this new methodological approach may shed light on how we learn to draw, and on how to teach. Neither Kozbelt nor Tchalenko has conducted any longitudinal study of the effects of training on novices. Chapter 5 outlines a method for longitudinal study, with findings from the case studies demonstrating a move from novice towards expert behaviour, as characterised by Tchalenko's research. The case studies assess changes in drawing students' abilities before and after drawing training, and relate these changes to quantitative analysis of accuracy.

Regarding the points highlighted above, Ruskin's idea of sharpened perception is explored in Chapters 5 and 6, relating his idea to enactive theory and exploring it in practice. Gregory's view of contingent vision is explored as a model for drawing perception in Chapters 5 and 6, Tchalenko and Miall's visuomotor findings are used as the basis for hypotheses for exploring the move from novice to expert drawing behaviour (See Chapter 4) and for the development of my drawing method (See Chapter 6), helping towards a characterisation of observational drawing defined by eye and hand movements. Noë 's view is used as a framework for development of an enactive theory of observational drawing, developed in Chapter 5. Nicolaïdes' view that drawing needs to use all the senses and experience is developed in the thesis, from both a practical and a theoretical perspective. His instruction to synchronise eye and hand movement forms the basis of the drawing method developed in the study (see Chapter 6). The method adapts Nicolaïdes' gestural method for quick life poses for a slower way of drawing from observation, and is more concerned with engagement than with representation. It combines his contour drawing exercise with glances to the drawing, in order to anchor the drawing spatially on the page, and produce a spatially accurate presentation of an object. In this way the thesis connects Nicolaïdes' teaching approach with subsequent scientific findings about the limits of ocular vision, and the need for touch and movement to elucidate visual perception.

In summary, the review establishes an argument for observation of movement, and for linking drawing theory with current cognitive science research. No one is adequately relating findings and discourse from the diverse fields of inquiry, and doing this will enrich and broaden our description and, more crucially, our understanding of the act of drawing and creativity. There is also a gap in knowledge about whether, what and how changes occur in novice students undergoing drawing training. This research study seeks to address these two issues, by offering a method of inquiry, and data from case studies to begin to explore the transition from novice to expert, and to apply new scientific findings to pedagogy and practice. The thesis uses Gregory's model of visual perception as a model for observational drawing, fleshed out with new knowledge about motor movements of drawing, to produce a practical system backed by scientific theory.

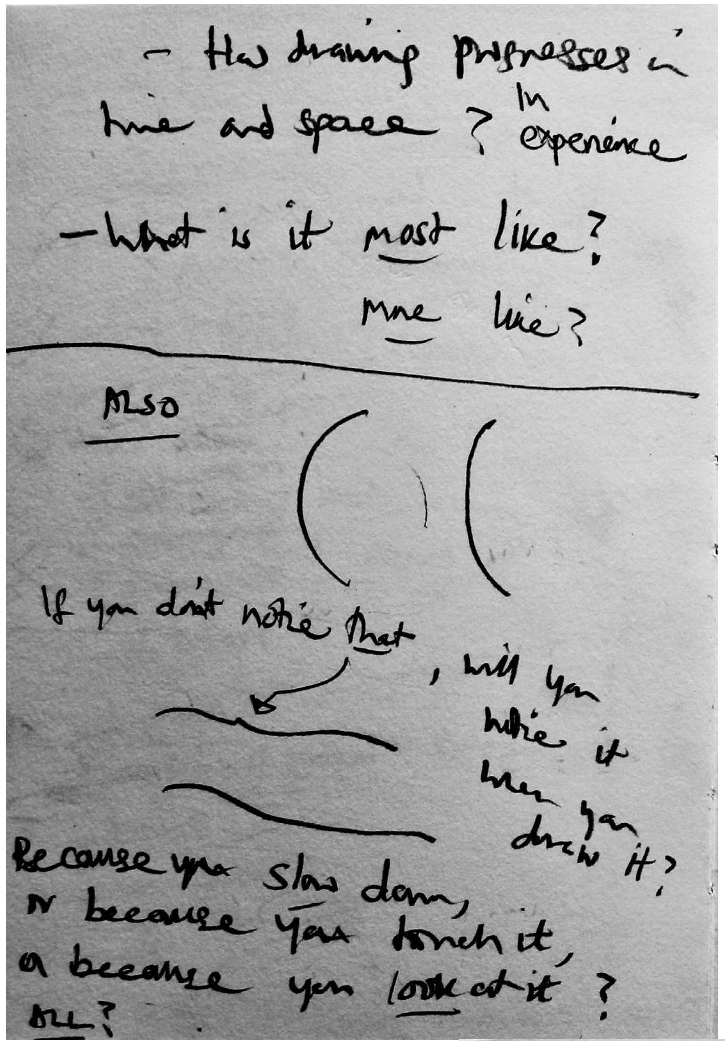
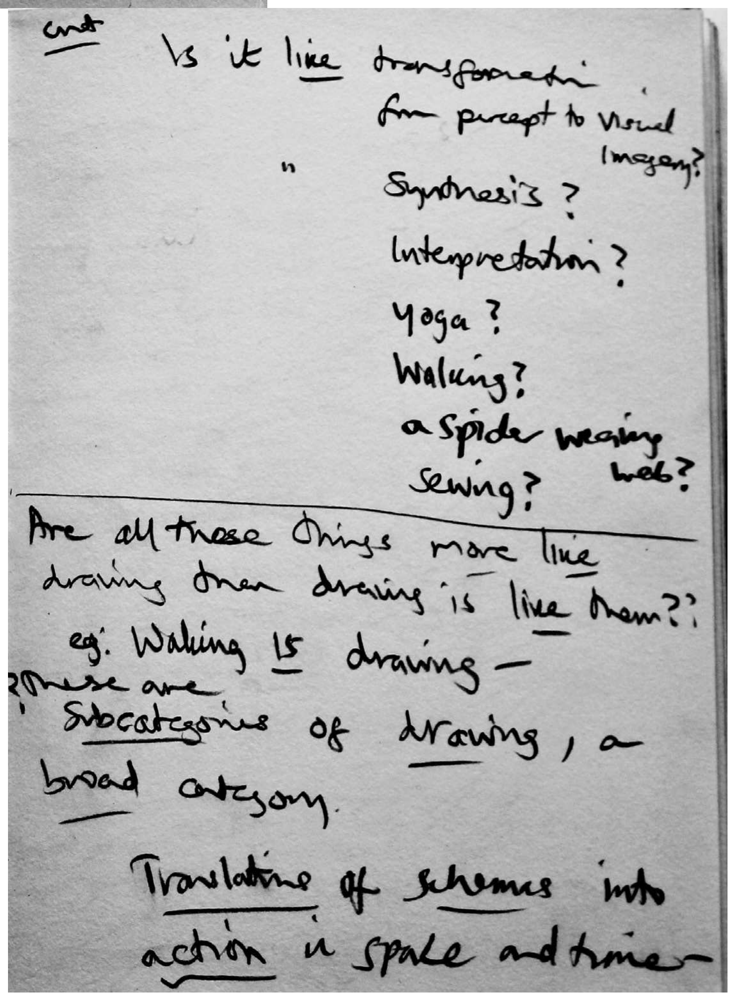


Fig. 3.1 Thinking drawing - What is drawing like? Does drawing help you to notice detail?



Chapter 3 Methodology

3.1 Introduction

My project was to characterise the action of observational drawing temporally and spatially, and to translate new scientific knowledge of these movements into drawing instructions.

My theoretical premise is that drawing requires an extra-ordinary way of perceiving – an assumption made by many, but on little empirical evidence. The methodological premise is that observation of the movements involved in this form of perception will shed light on the process and offer new understanding of observational drawing. In this way the study attended to non-propositional procedural knowledge, and to 'bodily thinking'.

Towards this characterisation, the study scrutinised the connection between scientific theories of observational drawing and practice, aiming to deepen the link between science and pedagogy, to develop scientifically informed drawing instructions, and to contribute to drawing theory. The method uses perceptual and conceptual drawing practices, quantitative analysis of eye and hand movements, and theoretical study to examine the hurdles to accuracy and conditions of drawing, to develop a comprehensive enactive model of how and why we move when we draw. Discussion and collaboration with scientists, theorists and drawing practitioners from a range of fields contributed to the development of methods and hypotheses explored.

Central to the method is the use of drawing as a research tool. The focus of research is on the role of physical movement in visual perception and drawing. The drawing methodology consists of 1) observation of the drawing process and 2) the use of drawing as a research methodology, to think, and to relate ideas and theories across fields. Hence my drawing practice as a form of investigation adopts two distinct approaches, which I refer to as perceptual and conceptual. The perceptual approach is a reflective engagement in observational drawing practice, while conceptual drawings are used as a way to explore, understand and organise ideas and information.

The initial hypothesis, stemming from art education, is that a definable 'unusual' way of looking at things allows accurate drawing. The aim is to show how 'looking, for line drawing' is distinct from the way we look at things most of the time for everyday living, when we use vision to rapidly identify objects, movement and spatial location. This chapter explains the methods used to search for observable evidence of an adapted, task-specific, mode of

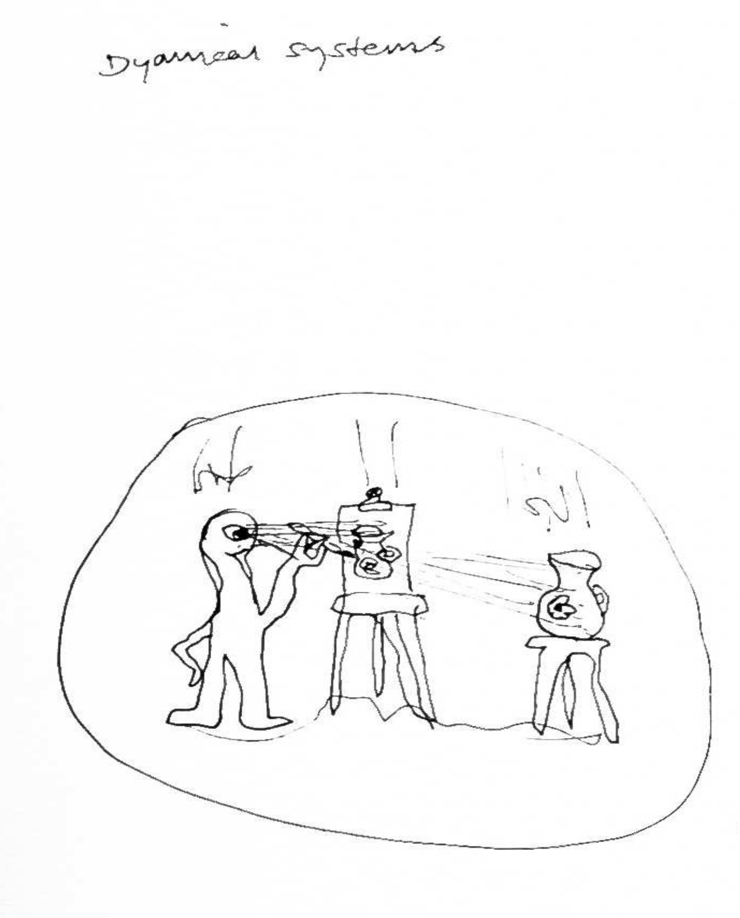


Fig. 3.2 Drawing as a dynamical system incorporating the drawer, the drawing and the world.

perception, for drawing.

The first step was to search for scientific support for this, in literature and in my own experiments. Would it follow that evidence of an unusual way of looking would correlate with the production of accurate drawing? I proposed a provisional set of requirements of vision, for accurate observational drawing, creating a prototypical model of 'looking, for drawing'. This included exploration of the relationships and patterns of fixation sequences and hand movements using eye tracking and video recording.

Can people learn to look at things in a different way, and if so, how? The methodological question of how to observe change was central to the study. My perspective comes from the drawing studio, stemming from my conscious experience of a transformation of perception resulting from drawing practice. Also I had talked to many artists about how drawing changes the way they see things. I aimed to develop an interdisciplinary method for observational microanalysis of the drawing process, and particularly of the process of learning to draw. I studied this by exploring the transition from novice to expert; the development of a 'drawing eye'. Characterising the drawing eye entailed questioning the relationships between perception and action and between the eye and hand. Where are artists looking while they draw? Are there discernible patterns in their eye movements? How does the eye inform the hand, and vice-versa? What do these eye paths suggest about cognitive activity during drawing? This led on to the question of how scientific findings could be applied to pedagogy, as well as a questioning of current models from the science of drawing.

A premise of the research was that recent developments in technology allow us to empirically test long and widely held, largely unsubstantiated, theories about how artists look at things with intent to draw them. As outlined in the literature review, approaching drawing from life as a problem to solve (i.e. achieving accuracy) may help us to move closer to a model that accounts for scientific cognitive theory and the experience of drawing. I wanted to offer a practical answer, by explaining how we use our eyes and hands, and how they interact during drawing. Despite its complexity, drawing entails a discrete observable behaviour with visible output. Observational drawing provides a correspondence between the action, the object being drawn, and the drawing on paper. Both the final drawing and the action can be quantitatively analysed.

The study was framed as a critical dialogue between art studio and science lab as this enabled me to ground theory and practice and tied in with a vital concern in practice-based PhD research about the role of visual thinking. The operating principle was to move back and forward between science and drawing, and between theory and practice, to see what insights and connections emerged from the contrasting methods. I began with the plan to test pedagogic ideas scientifically, but by the end of the study I realised that knowledge emerged where practice and science converged, by connecting theory and practice across fields. In the same way as the dialogue and synchronization of eye and hand was identified as key to drawing, the conversation between drawing and science was at the centre of the methodology, including dialogues and collaborations with individual scientists and drawing practitioners, teachers and students. The questions about the inter-relationship between perception and action, in the specific case of eye and hand movements in observational line drawing, required an approach informed by both science and experience. Real life experience urges us to step out of restrictive experimental frameworks, and to explore more than can be 'controlled' for. The scientific strand of my methodology used video analysis methods while the drawing practice entailed consideration of how the eye and hand may be contributing to perception and cognition.

Two significant factors that advanced the research were the development and use of drawing as a methodology, and the formation of the interdisciplinary research group, called International Drawing and Cognition Research. The latter opened the door to debate and exploration of drawing processes with leading researchers and practitioners from the cognitive science of drawing, education, medicine, and facilitated the discussions needed for this project. Members of the research network attended our symposium series, *Thinking through Drawing*, fostering cross-disciplinary debate and collaboration. In the first year of formation of the group our conference proceedings were published by Teachers College, Columbia University, under the title *Thinking through drawing: practice into knowledge* (Kantrowitz, Brew and Fava 2011).

Aims

Through the development of interdisciplinary method I aimed to:

1) Connect scientific theories of observational drawing with practice and pedagogy.

2) Contribute quantitative data to deepen our understanding of the orchestration of movements involved in 'looking, for drawing'.

3) Explore how we learn to draw and the move from novice to expert, and what this may reveal about the perceptual processes of drawing.

4) To develop new observational drawing practices informed by recent findings in cognitive science, and from this develop new teaching instructions.

3.2 Method of enquiry

How to observe drawing

Crucially, the research was carried out from my perspective as a drawer: my own practice gave me some understanding of the processes involved and informed the questions I was asking and the avenues I explored; this provided a feedback loop within the research whereby my experience and practice questioned lab findings, and lab findings and tests questioned experience and reflection from the art studio and drawing classes.

Van Sommers argument that '…normal perceptual commerce with objects' is not 'adequate' to the task (1984 p.132), and Tchalenko's exploration of hand-eye behaviour in observational drawing, provided direction and structure for practical investigation, searching for the conditions of drawing, both in terms of movements and perception.

The investigation also correlated products with process, linking observations of eye and hand interactions with quantitative analysis of accuracy of copying. A crucial development in drawing research methodology began in the 1970s with Van Sommers' sustained observational study of processes of graphic production. Van Sommers observed and documented the drawing process, looking at the order of execution and strategies of drawing, but did not interrogate the micro-level of hand and eye movements. In the 1980s and 1990s, Tchalenko, Solso and Cohen continued in this paradigm, empirically investigating eye and hand behaviour and interaction during drawing. Soon after, Miall began a systematic study of general drawing and copying behaviour, working in collaboration with Tchalenko, combining eye tracking observations with fMRI data. My methodology builds from their work, combining empirical observation methods with several forms of reflective drawing practice, review of accounts from practitioners and teachers, and finally the development of my own drawing instruction, informed by behavioural and cognitive scientific findings. Empirical findings were analysed with conventional scientific methods, established within eye tracking research (see Tchalenko 2009a) and scrutinised using drawing practice and teaching. The quantitative study looked for changes within participants, before and after training, in their approaches to the task of drawing, as this is where the largest gap exists in research and in accounts of the drawing process.

A generative methodology evolved during the study, along with a deepening understanding of scientific methods and the potential role of drawing as a way of investigating and knowing. With a hybrid theoretical framework built from findings and perspectives of Tchalenko, Gregory, Noë, Chemero and Ingold, I used drawing and conversation as methodologies to examine the drawer's eyes, hands, body and objects in the world as a dynamic system (see Chemero 2009).

Observing the eye, and observing looking

One way to try to understand what may underpin the act of accurate drawing is to look at artists' eye movements, as a manifestation of brain function that is observable in natural settings. The eye moves in distinctive ways, capturing information and playing a crucial role in action. The loci of eye fixations give us data about the loci of visual attention, especially when supported, as in this case, by physical production of segments of lines in a drawing. If drawing demands a different from usual, and more comprehensive, visual analysis of the object, we would expect to find this reflected in the eye path and approach of drawers. (see Land 2006, Findlay and Gilchrist 2003, Hayhoe & Ballard 2005). My starting point was to look at eye and hand behaviour. I carried this out by working for two years in the Drawing and Cognition Project with Tchalenko, helping with eye tracking experiments and analysis of data. During this time I developed a methodology for my own observational study of Edwards' students.

I began by collecting data relating to looking, as distinct from perception, as looking is an observable action. When I use the word 'looking' I refer to the act of directing the eyes, which we can record, by observing eye movements. In contrast, it is impossible to directly observe perception in others; we have access only indirectly, via accounts of perception. We can attempt to interpret eye movements and brain scan images in terms of perception, but this relies on accounts of participants' perceptual experience. The study of observational drawing does give us an additional particular insight into perception, by offering us visual representations relating to the drawers' perceptions. However this raises the question of whether there is a stable internal representation, that is drawn from, or whether perception is a dynamic process (see Chemero 2009). I believe that drawings are most usefully interpreted in tandem with the drawers' account of their experience of looking, and of making the drawing. Frith writes that, after a period of behaviourist dominance:

> Now we psychologists are back studying subjective experiences: perceptions, recollections, intentions. But the problem remains: The mental things that we study have a completely different status from the material things that other scientists study. The only way that I can know about the things in your mind is because you tell me about them. (Frith 2007 p.6)

This clarification provides a rationale for my research approach that relates quantitative

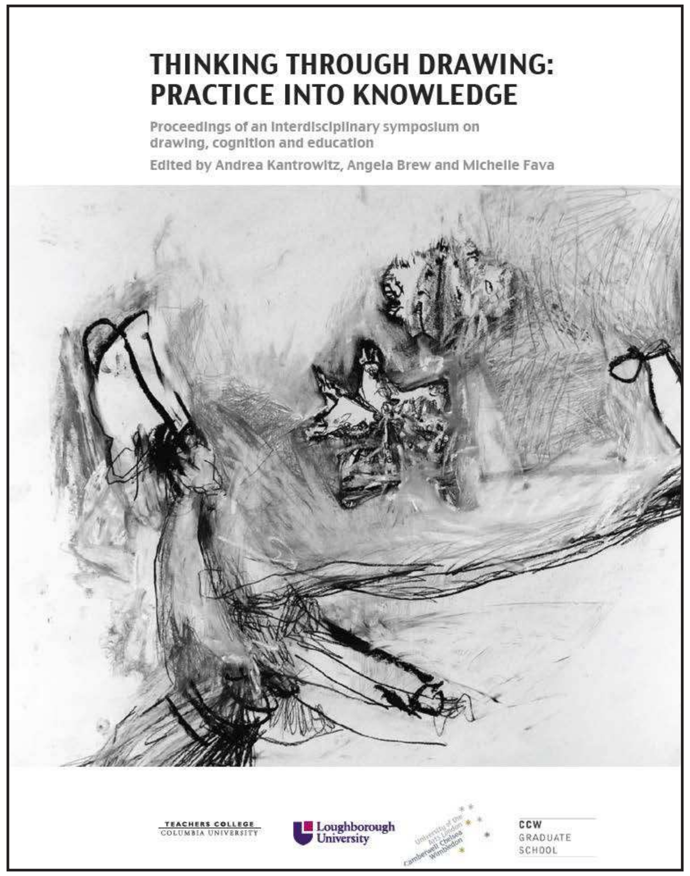

THINKING THROUGH DRAWING:
PRACTICE INTO KNOWLEDGE
Proceedings of an interdisciplinary symposium on drawing, cognition and education
Edited by Andrea Kantrowitz, Angela Brew and Michelle Fava

Fig. 3.3 Cover of TtD symposium proceedings book 2011

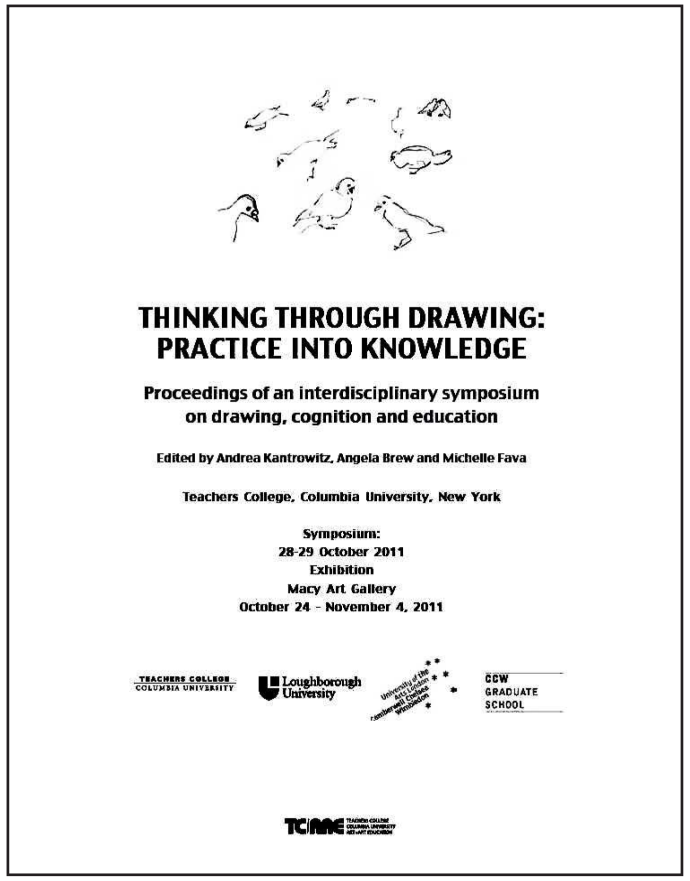

THINKING THROUGH DRAWING:
PRACTICE INTO KNOWLEDGE
Proceedings of an interdisciplinary symposium on drawing, cognition and education
Edited by Andrea Kantrowitz, Angela Brew and Michelle Fava
Teachers College, Columbia University, New York
Symposium:
28-29 October 2011
Exhibition
Macy Art Gallery
October 24 - November 4, 2011

Fig. 3.4 Title page of TtD symposium proceedings book 2011

findings about eye and hand movements to accounts of perception; the former being observable, while perception can be studied only indirectly. For this reason the research topic demands a 'real-world' approach, attending to accounts of conscious experience, and behaviour in natural settings, and relating them to lab science, for example fMRI brain scanning, or eye tracking. Moreover this raises the intriguing question of whether drawings can communicate 'the things in your mind' that Frith refers to, and how we can interpret drawings in terms of perception.

Interdisciplinary study and conversations

The aim of interdisciplinary research is to contribute by linking theory and understanding from domains of research – in the same way that the drawer tries to attend to and relate the parts and the whole in order to articulate a new idea, an innovative approach and new knowledge. My research operated in gaps between fields; I was trying to grasp and connect huge areas of scientific, philosophical and pedagogic theory. To this end the hybrid methodology was developed, combining scientific and drawing practices with the aim of making connections between hitherto unrelated ideas and findings. To use Merleau-Ponty's metaphor, interdisciplinary study attends to a net of relationships:

> …the painter throws away the fish and keeps the net. His look appropriates correspondences, questions, and answers which, in the world, are revealed only inaudibly and always smothered in the stupor of objects. He strips them, frees them, and looks for a more agile body for them. (Merleau-Ponty 1973 p.47)

Scientific research has developed some useful provisional models of the physics and cognition of observational drawing but these need further elaboration and testing, including longitudinal study of drawing students, consideration of feedback and assessment processes, more exploration of mental imagery, internal representations, motor plans and the relationship between perception and action. This will significantly contribute to research on brain plasticity and learning, and, through our interdisciplinary collaborations and communication, to the practical educational application of new knowledge about drawing and cognition (see Kantrowitz, Brew and Fava 2011). In the first part of the research my empirical quantitative study of eye and hand movements contributed to the scientific model that informed the practical exploration.

To further my interdisciplinary engagement in 2011 I co-founded the International Drawing and Cognition Research Group with fellow doctoral students Michelle Fava and Andrea Kantrowitz, to bring together experts and researchers from a wide range of disciplines to

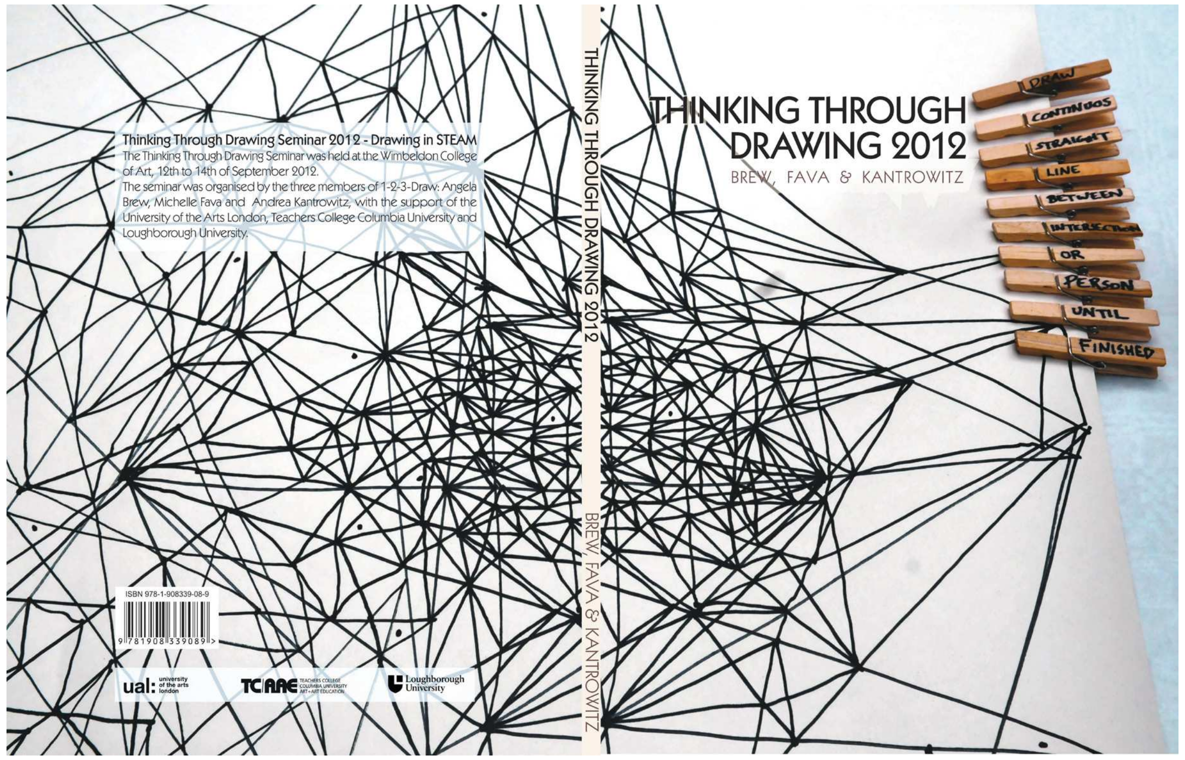


Fig. 3.5 Book cover TtD symposium proceedings 2012

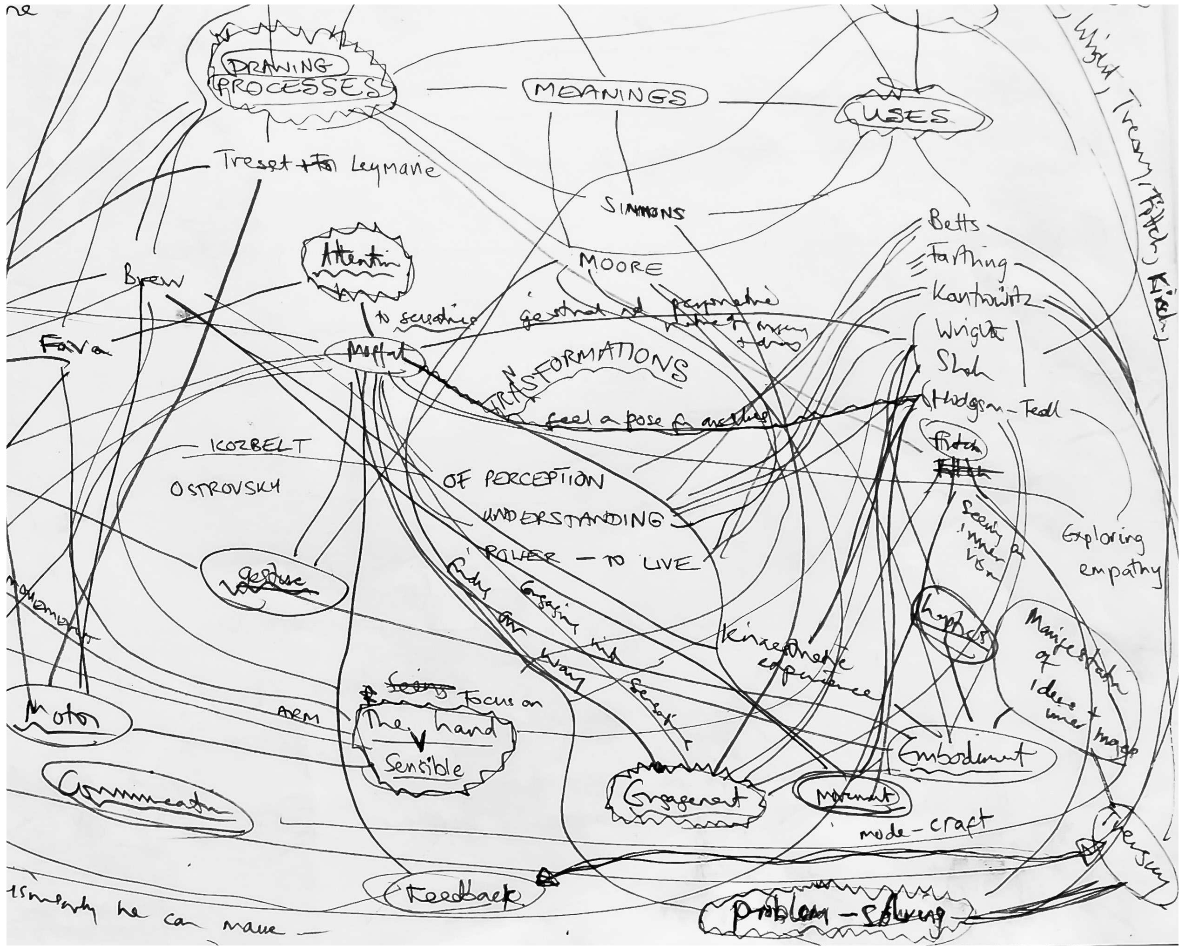


Fig. 3.6 Excerpt of map of members of International Drawing and Cognition Research and their research interests

explore drawing and to facilitate interdisciplinary dialogue.   We convened a symposium at Columbia University, bringing together researchers and practitioners from across fields. As a result I was able to converse with a range of experts, from cognitive science, medicine, social science, architecture, design, education, fine art and art history. The group now has over 600 members worldwide, and meets at our annual *Thinking through Drawing* symposia. To date we have run three symposiums, with the focus on translational research, exploring how theory can be applied in medicine, education and a range of professions. This has fostered many relevant conversations, and offered various methodological approaches. Hence much of my material comes from conversations with these experts, including from our conference proceedings and video recordings of presentations and debates. Cognitive scientists Barbara Tversky and David Kirsh have been particularly significant in the development of my methodology. They study the role of gesture and drawing in thinking processes and perception. Their findings are cited both to support the use of drawing as a research methodology, and to give insights into the research subject, the motor and perceptual processes of drawing.

Schön's action research model (Schön 1991) involved a broad operational framework for the reflective and looping process between studio, lab and teaching practice. His focus was on collaborative research and learning processes, and his interest in practical change fits well with my study aims, both in terms of my research subject and methods. His notion of 'thinking on your feet' ties in closely with my drawing methodology, using the hand to think, by drawing.

Using embodied and enactive theories of cognition

As well as offering a framework for understanding perception in action, recent embodied and enactive research offers methodological recommendations for the study of drawing, with researchers sharing an interest in the impact of the physicality of the body on cognitive processes and seeking to integrate quantifiable aspects of brain function and activity with experiential findings (see Lakoff & Johnson 1999, Johnson M 1987, Petitot et al. 1999, Varela et al. 1993). Embodied cognition offers a theoretical framework which recognises bodily interactions with the world as playing a part in understanding and thinking processes. Active vision theory as outlined in chapter 2 (Findlay and Gilchrist 2003) recognises the physicality of the eye, its active functioning within the human body, and the limits, and scope, of perception. Active vision theory and embodied cognition theory underpin my methodology.

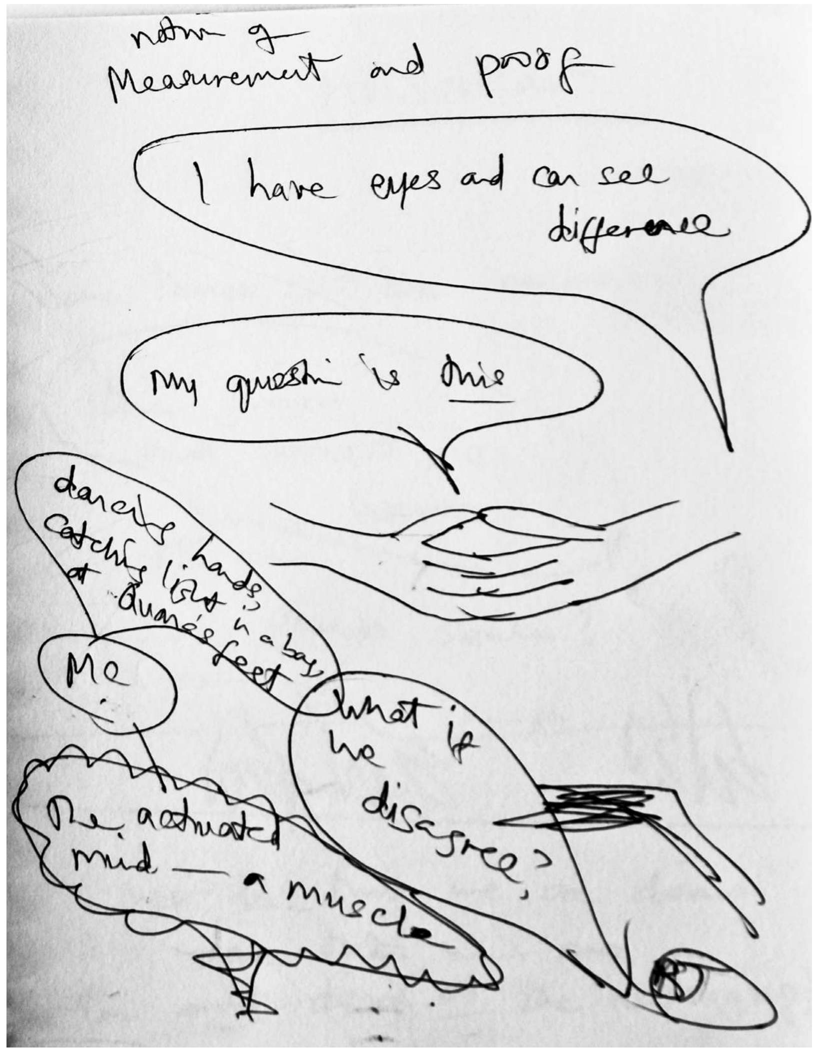


Fig. 3.7 Observational drawing - thinking on the page about the conversation between eye and hand. Made at *Thinking through Drawing* symposium 2012

Drawing for research

Drawing as a research method facilitates exploration across disciplines, and offers a way to think on paper and with the hand. I used drawing in two ways: in reflective observational drawing practice, defined as perceptual drawing, and as a conceptual research tool to explore ideas, make connections and to organise the thesis structure and narrative. Observational (perceptual) drawing practice served two purposes, to reflect on the coordination of eye and hand movements, as well as on perceptual experience.

This experience, and consideration of the processes of observational drawing, informed the research methods, in terms of attention to parts and the whole, checking relationships, adjusting the parts until they work together. I worked on chapters in tandem, connecting theory with practice across disciplines and making links between theory and practice. A thesis needs to work as a whole, and in detail, with consideration of structure and form of, as well as content. In this way the discipline of observational drawing facilitated writing and the making of conceptual drawings, for thinking and organising. Observational drawing operated as a rehearsal space, for practising relational analysis. At points the study teases apart the process of drawing to expose common assumptions about vision that may be misleading, to try to observe details, and then tie the process back together to reveal new patterns of connection.

I began with the general notion that I could draw the thesis in some way. This demanded that I examine the sort of drawing I was using. Was I trying to illustrate the argument? Was I drawing a comic strip of the thesis? I found that most of my drawings seemed unreadable, even to myself. I realised that these drawings were my thinking work, and that another type of communicative drawing was needed for the final thesis. I made these close to the end of writing up, at a point when the pieces of the jigsaw had fallen into place and when I had a clear idea of the structure and content. Even in the final stages of writing up the thesis I found that the drawings often led to new insights and ideas. The thesis was constructed and followed using conceptual drawings for every chapter and for the threads of argument.

This approach was based on Gregory's model of vision as a research process; the eye searches for information, collects it, transforms it, interprets it (gives meaning) and presents it. In this case drawing is the research process, adding to the power of the eye with the hand, extending working and short term memory using the drawn image on the paper. From this view my PhD project is 'research about research'. This is a useful way to conceive it, as all I learn about looking and vision adds to my understanding of the research process for Ph.D study. Halliburton wrote of looking 'Looking at something, understanding and conceiving it,

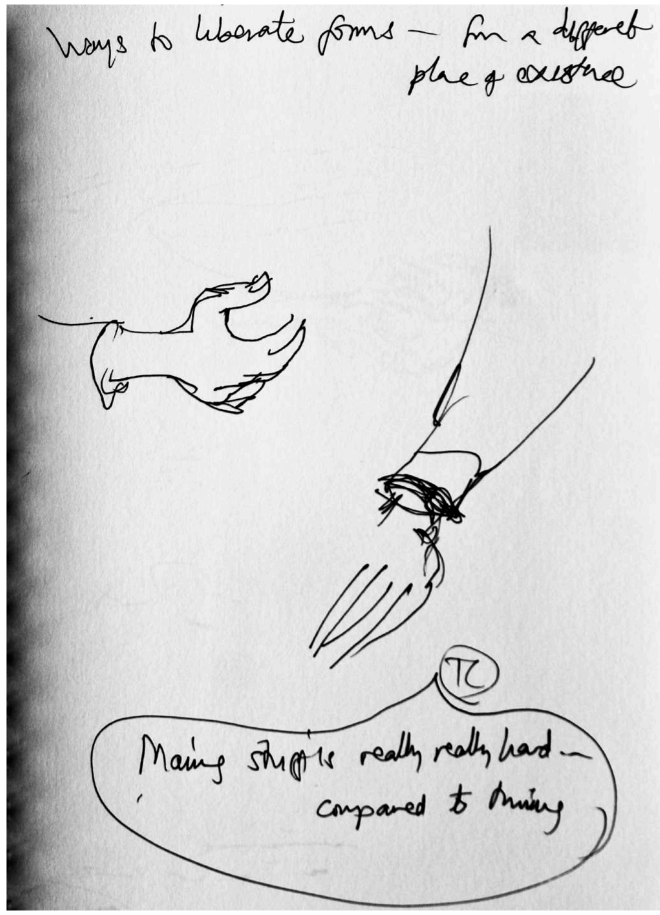


Fig. 3.8 Observational drawing, made at *Thinking through Drawing* symposium 2012

choosing, access to it, - all these ways of behaving are constitutive for … inquiry' (Halliburton 1981 p7).

The methodology for the study is founded on the view that the process of drawing, like active vision, is a powerful research tool. Gregory proposes that vision itself is hypothesis testing, as outlined in Chapter 2 (and see Gregory 1997). A dynamic model of vision entails cognitive processes of planning (intention), searching for and collecting information (attention), making hypotheses about what you are seeing (best guesses), checking information, interpreting, and integrating information into a meaningful whole. Drawing has an intimate relationship with vision, whereby it relies on it but also, importantly, questions, tests and advises it. Drawing has an established place and history in invention and creation, and as a thinking tool.

Thinking through drawing

Drawing tests ideas on paper (Fish & Scrivener 1990, Kirsh 2011, Tversky & Suwa 2009). Researchers argue that thought processes happen on the page, and in the hand, challenging the theory that thinking happens only in the brain (Noë 2009, O' Regan 1992). In contemporary fine art and design research, drawing is argued to be knowledge-producing and a thinking tool (see McGuirk 2011, McDonald 2010). Specifically, in this case, observational drawing can test visual hypotheses, and confirm or refute them. This is central to my thesis, as it is relevant to the question of why and how perception is transformed by drawing. Drawing practice informs vision. Both visual perception and drawing have speculative qualities. In this way drawing becomes both research subject, and method, offering a useful model both for the study of vision itself, and as a method. This has a significant bearing on both my practice and critical analysis. An objective of my research is to explore and use visual research methods, especially drawing. On a fundamental level the more I learn about vision and drawing, the more I understand about the research process, and vice versa. This informs all my activity and decisions about paths to take and questions to ask. The final chapter of the thesis, linking results and findings from the various experiments and methods, makes particular use of visual drawing techniques to analyse and present information from the field and experimental findings. In the final chapter a discussion of methodology examines how the challenges posed me in this research project were met, and the success of my efforts to apply alternative ways of thinking and communicating.

Conceptual drawings - drawing drawing

Conceptual drawing practice was used as a mode of inquiry to scrutinise hypotheses and

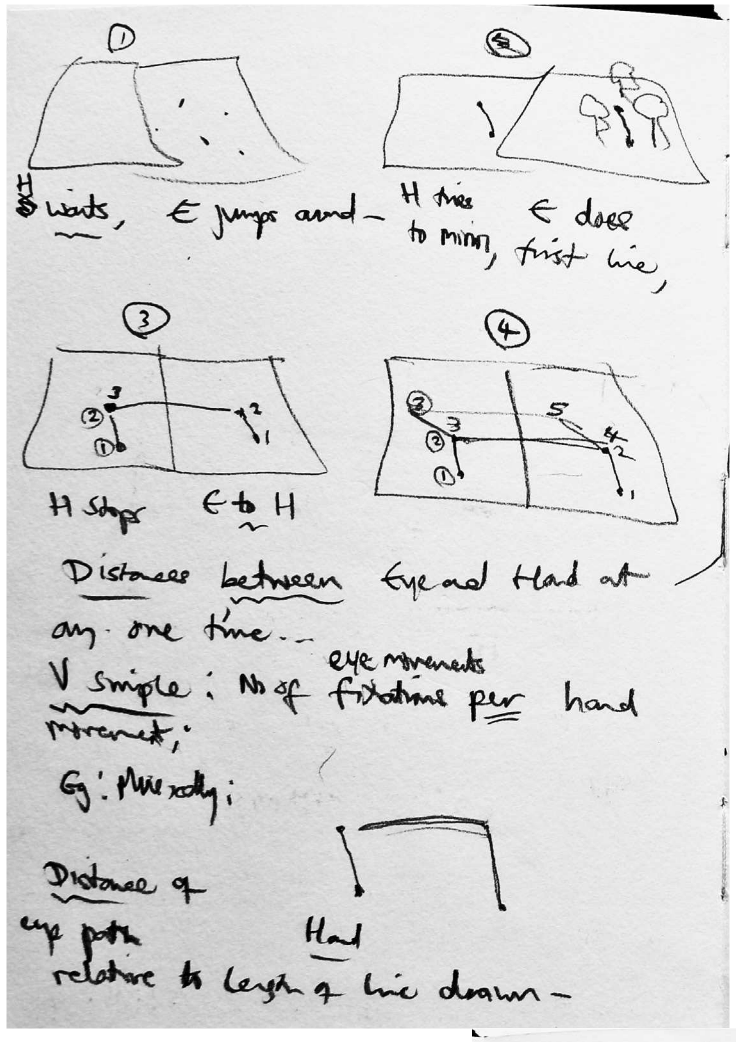
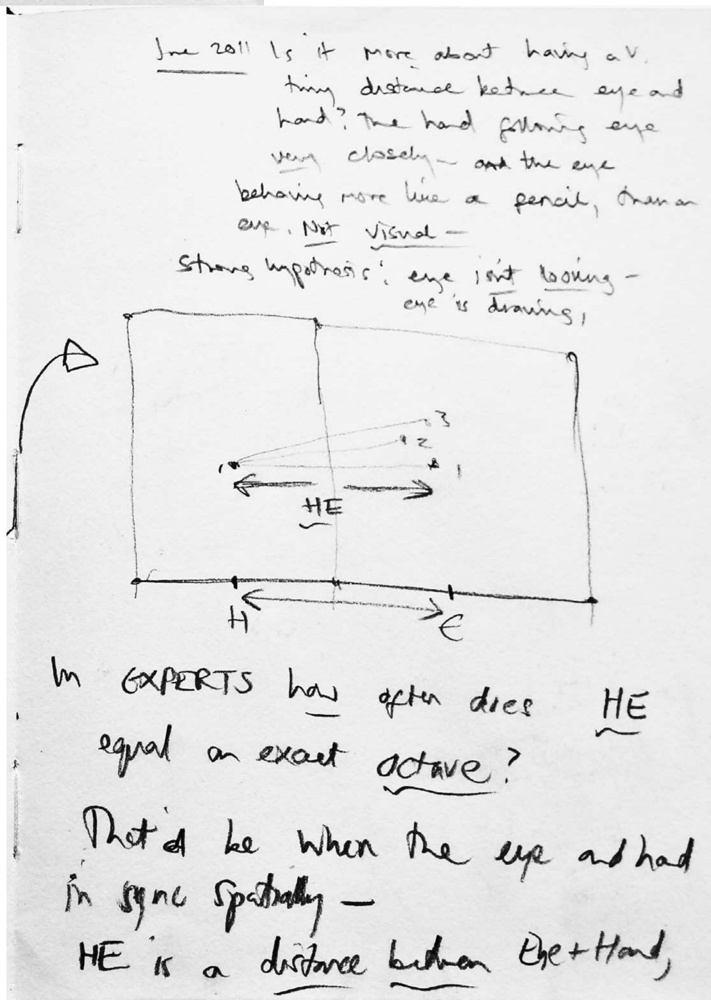


Fig. 3.9 Thinking on the page about the interaction between eye and hand.



findings from eye tracking research relating to 'looking; for drawing' and the production of accurate observational drawings, and to map and relate concepts and findings across disciplines.

The language of drawing provides the means to gather insight, to think, to organise, clarify, frame and share knowledge. I used a range of visual methods to map, manipulate and assess information and data. Various styles of conceptual drawings served different functions. Radiating 'mind maps' were used for thinking, but not for presenting arguments. Concentric mappings are hard to follow in terms of sequential argument, as the points radiate from a central premise, but do not communicate the order of an argument to a reader (see Tversky 2011b p.511).

Perceptual drawings - observational drawing practice

I explored findings from drawing science in practice, using techniques developed during my Drawing Masters project and ethnographic observational methods to record and reflect on practice, adopting methods suggested by Pink.(2007). This was carried out in my studio and in the field, recorded by scanning and photographing all drawings and keeping a diary of reflections and insights. These fed back into the rest of the research, suggesting ideas for empirical experiments and further investigation.

I drew in order to participate in my subject of study, to gain insights into the process of learning to draw, and the act of drawing. The approach entailed a straightforward engagement in the practice of drawing from observation, with reflection on my perceptual experience, focusing on changes in experience taking part in the activity to gain insight into behaviour and skill acquisition. In ethnographic terms, in my studio and on the Betty Edwards' drawing course in Santa Barbara, I acted as a participant-observer (see Schön 1991, Pink 2007). I used video to analyse students' and my own behaviour, using the same method as that of my quantitative study (see below, empirical methods) of breaking down the action into temporal and spatial elements, to discern rhythm and synchronization of eye and hand.

As outlined in the introduction, the observational drawing method developed for this study acts as a research tool and a form of engagement, rather than as a visual representational tool. Lyons (2009) refers to her research drawing method as delineation, to specify the translational interpretive process from sensations to line.

The output of my drawing practice was interpreted in the context of theory from cognitive science, and in relation to my own findings from the study of drawing students. Collections of

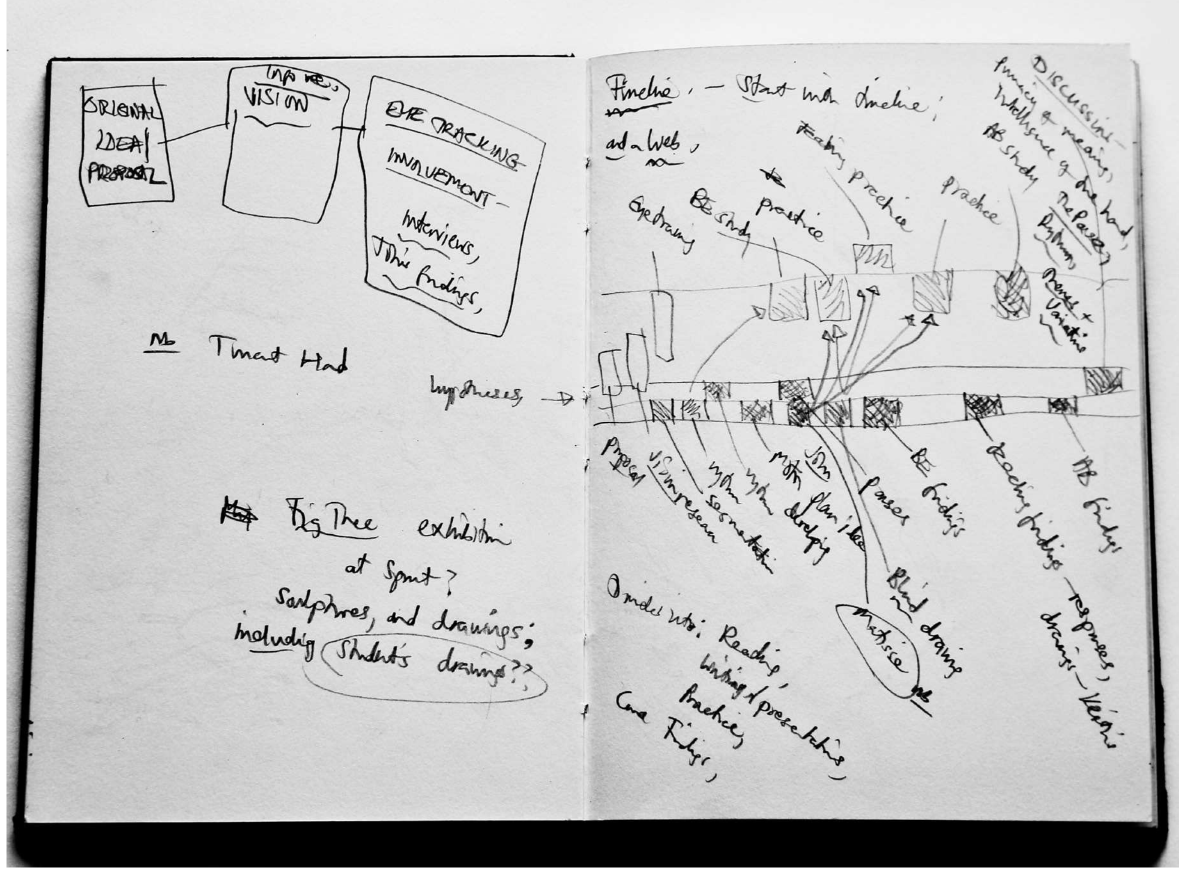


Fig. 3.10 Thinking drawing - thinking about the structure of the thesis.

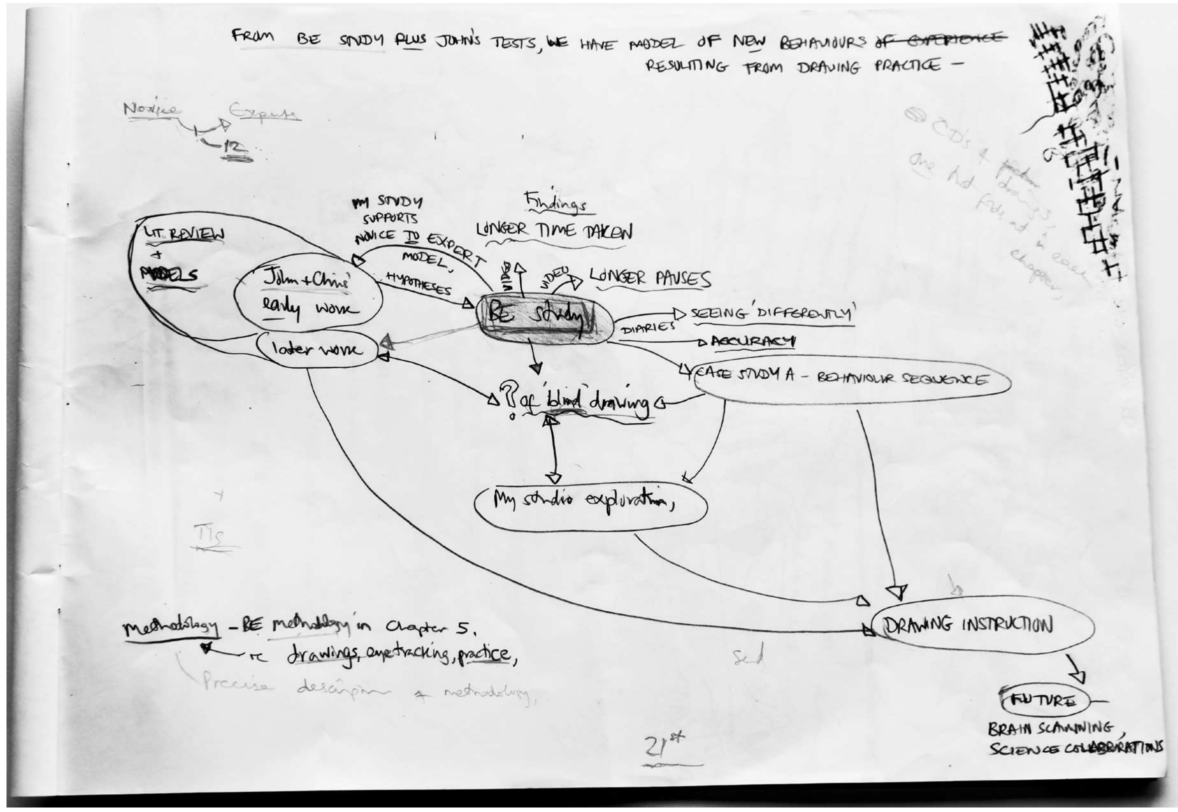


Fig. 3.11 Thinking drawing, about the structure and progression of the research

drawings are linked to reflective accounts of my experience and to current scientific theories and findings in maps and drawings. Drawing diaries outline how insights from my own studio practice influenced the direction of my quantitative studies. Records were kept in diaries and portfolios, and scans stored in computer files.

Approaching the thesis as a drawing

As outlined above my research project is conceived as a drawing, needing a dynamic approach to focus attention on the whole and the parts. In observational drawing I use a strategy akin to way-faring, as distinct from route-finding: this entails attention to details, anchoring each segment to the others, and finding your way by checking relationships as you go. This is distinct from outlining methods of drawing, where the whole is sketched out and details anchored by the whole. In my style of drawing, details connect to details, and eventually a whole emerges. Thus, in the case of my thesis, the argument emerged from connecting the details.

The process of observational drawing acts for me as an affirmation of my ability to solve problems, to relate parts and build a coherent whole. My observational drawing method is detail-focused; a way-faring system relying on an on-going awareness of position in relation to nearby points. If the parts are accurately related the whole will emerge. In this way it is deductive, each part following from others, and assessed in relation to the others. The premise is that this approach is more open, allowing new knowledge of the whole to emerge through accurate articulation of the parts. One does not anticipate the final drawing, and does not depict the object. It is an explorative process. In this way the content mirrored the form, with the research subject being how we articulate parts into wholes. This extended to the level of temporal and spatial considerations; how does one order the drawing / the research, and how does one physically present it?

Approaching the thesis itself as a drawing, i.e. using drawing as a methodology, facilitated thought and articulation of parts and whole, shedding light both on the research subject and research processes.

Arenas

I carried out research in the Drawing and Cognition Project laboratory at Camberwell College of Art, in my drawing studio and in drawing classes in various locations.

Empirical work was carried out under the leadership of Dr John Tchalenko, and in a temporary lab I set up in Santa Barbara, US, to conduct systematic tests of students' eye and

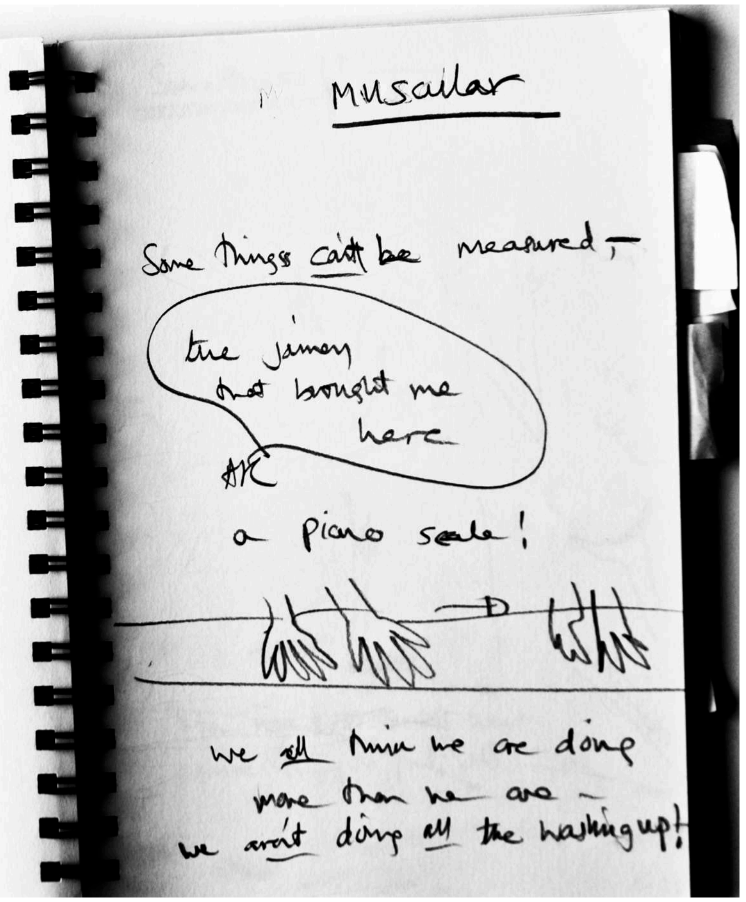


Fig. 3.12 Thinking on the page about the interaction between eye and hand

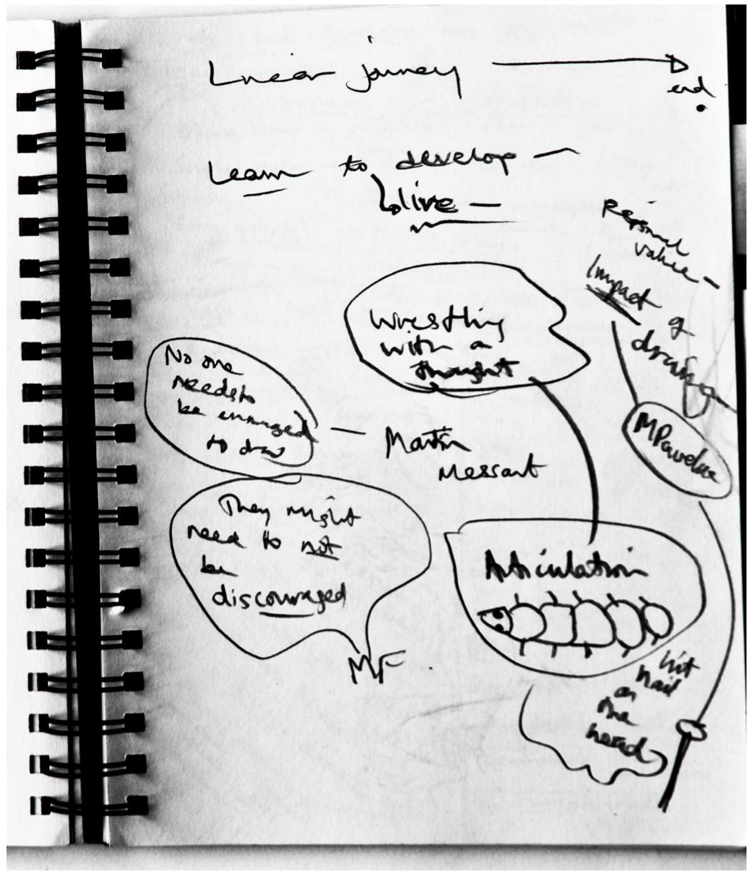


Fig. 3.13 Thinking about thought and articulation

hand movements, before and after undergoing intensive drawing tuition and practice.

As outlined above, I questioned and explored findings and hypotheses from cognitive science and art education in drawing experiments in my studio and in teaching practice. Field study was carried out in various locations, including other drawing classes and artists' studios, in order to record and observe behaviour and experience in natural settings, and to challenge findings from scientific lab experiments and my own drawing practice.

Chronology of research

It is worth briefly summarising the chronology of my use of methods, to clarify the development of the methodology and how it was applied. At the onset working on the literature review and in the Drawing and Cognition Project informed decisions about approach and research subject. Assisting with eye tracking experiments and data analysis prepared the ground for my empirical study of eye and hand movements, and led to the decision to study drawing movements, and particularly the acquisition of drawing competencies. At this point I developed interview methods, to connect experience of practitioners with observations of their movement. I then designed and conducted my quantitative study of the move from novice towards expert drawer, and travelled to San Diego and Santa Barbara, California to observe Edwards' teaching methods and to make three case studies of her students.

In the second phase of research, documented in Part 2 of the thesis, I moved into a phase of practical exploration of sceintific, pedagogic and philosophical theory, using drawing and teaching practice. With knowledge and findings from my own study, and from working in the Drawing and Cognition Project, I developed a model of expert drawing behaviour to be further explored by reflective drawing and teaching practice and conceptual relational drawings. This phase of study began by my making a drawing to explore how enactive perception theory impacts on observational drawing practice and pedagogy. See Chapter 5. Following from this I formulated drawing instructions grounded in the new science of drawing movement, and explored motor and sensory processes. These new methods were explored through my own practice and teaching. From 2010 I began conversations with fellow doctoral researchers Andrea Kantrowitz and Michelle Fava, as outlined above.

Above, I have given an outline of the general approaches considered most appropriate for the study. Below in 3.3 I show how these methods were used. As explained the central

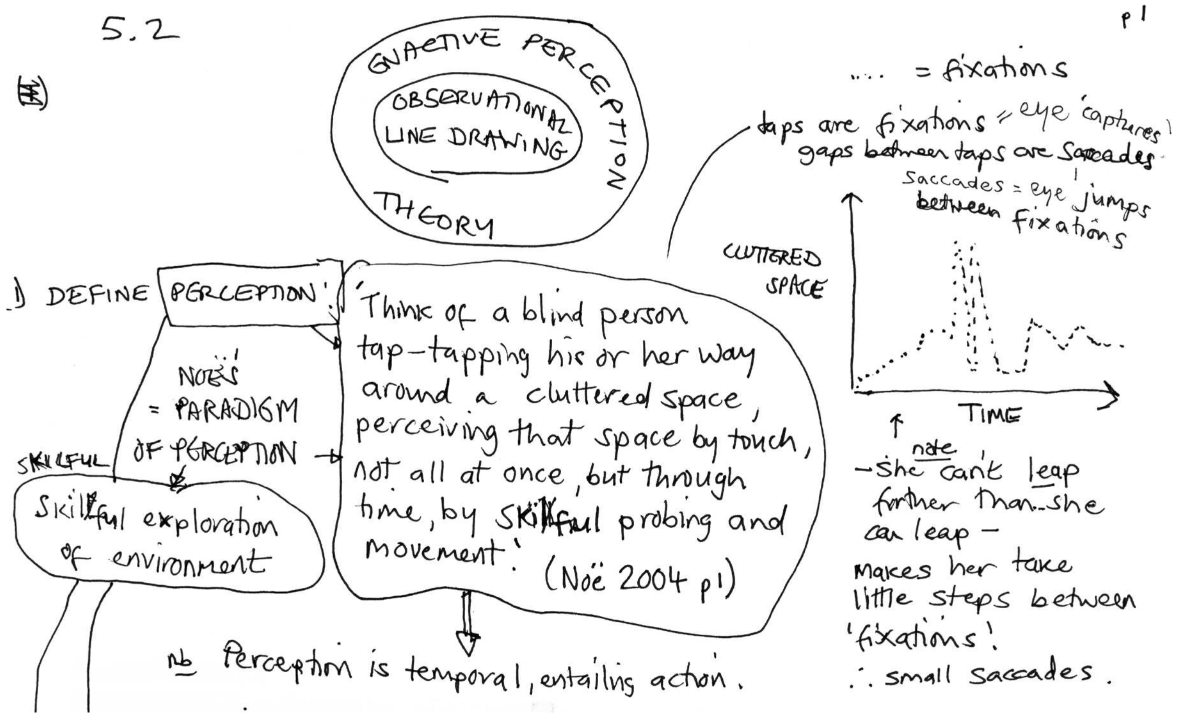


Fig. 3.14 Insight through drawing - to understand temporal aspects of vision, and vision as 'touch at a distance'.

methodology was drawing, as a relational tool for thinking, visualising, organising information, and for reflection on practice and teaching.

3.3 Methods

The use of the various methods are outlined below, with details of data sought, data collection and procedure, analysis, presentation and interpretation for the empirical study.

Conceptual drawing practice

Each chapter exists as drawings as well as text. Conceptual mapping drawings resolved and then described the structure of chapters, and annotated 'flow' drawings explored the progression of the thesis.

In Chapter 5 the argument is presented through annotated drawings rather than text, allowing a less linear progression, but maintaining a clear thread to follow. This method came about after trying various forms of 'mind maps' and illustrative drawing, to grasp and elucidate ideas and textual drafts. A cyclical process developed, of making drawings, writing from the drawings, and then drawing from the writing, in an effort to develop arguments.

I explored how ideas could exist and be articulated visually, within 'chapter-worlds'. Writing up in this way became a conversation between text and drawings, helping to devise ways to discuss and interpret data and ideas.

Observational drawing practice

Drawing projects

a) In November 2007 I drew line portraits for 5 days, for at least 6 hours every day. At the end of the week I was having a conversation with someone and found myself unable to concentrate on what she was saying. I realised I was looking at her in what Edwards calls 'the drawing mode' – her face appeared to me as lines to be drawn. This begged the question whether other artists experience this, and whether there is a way to explore this further, in the lab or in the studio. In this case my drawing practice acted as a preliminary pointer helping me frame questions for study, and initiating a cycle of questioning between lab and studio.

b) July 2009. Participation in Edwards' 5-day intensive drawing course. I kept a detailed record consisting of all the drawings I produced, audio recordings of the sessions, and a diary of my reflections. (See Chapter 4, 6 and appendices).

c) Exploration of Matisse's themes and variations. Matisse's method of repeated observational studies (themes) of one subject, followed by looser quicker drawings (variations), is the method I had used for 20 years of professional practice between 1981 and 2006. My Masters study examined this method: I made 450 drawings of the same still life, and filmed my own eye and hand movements. I compared this drawing process to the process of learning to play a piece of piano music. Observational drawing is analogous to the process of sight-reading, practising and performance. My Masters study raised questions about the use of motor memory, and whether one can learn a visual image in the same way one can learn a piece of music. Do you still need to look at the image in order to draw it accurately? I continued this investigation in the context of Tchalenko's cognitive interpretation of Matisse's execution of drawings. The impetus for this was to explore his findings in practice, and examine experientially the differences between the early 'theme' stages of drawing and the following 'variations'. This has potential to shed further light on differences between types of observational drawing and ways of looking. Drawing the same image repeatedly is an interesting way to study the learning process, and also offers an experimental method where the original subject or image is constant. My provisional findings from my Masters study suggested that, for me, even after 450 drawings made of the same still life, I was unable to draw it accurately from memory, either motor or visual. I simplified my subject and attempted to draw just one element, a blue phial, from memory. This was more successful but still surprisingly hard for me to remember. This may say more about me than about the complexity of the process, however my continuing exploration of motor memory and visual memory led to ideas for observing how repeated 'theme' studies may affect ways of looking. See Chapter 6 for examples of drawings.

d) I began to translate Tchalenko's findings into drawing instructions, and developed a new method, hinging on temporal awareness of eye and hand coordination. Trying out observational drawing and teaching methods based on recent scientific findings became central to the research from July 09 onwards. The aims were:

(i) to explore how to practice, learn and teach observational drawing; (ii) to explore existing scientific and educational theory. From July 09 – Sept 11 I taught drawing to novice students, one-to-one and in groups. I recorded students' responses to instruction, in the form of their drawings, their experiential accounts and my observations of their reactions to the instruction. I documented my insights and where possible collated these with copies of students' drawings.

e) In March 2011 I began teaching a weekly drawing class called Drawing Growth in Brockwell

Community Gardens (www.brockwellgreenhouses.org.uk/), to sustain my own practice by drawing the same plants repeatedly each week to track growth, and to test drawing methods with students. Specifically we explored motor methods of drawing and the proposition that the eye and the hand converse, and learn a new articulated and synchronised way of looking. Feedback from students was collected via e mail, and drawings and comments posted on a page of the community garden's website (http://www.brockwellgreenhouses.org.uk/welcome/whats-on/adult-courses/). See Chapter 6 and DVD for images of drawings.

f) I taught my motor-based method at classes at Teachers' College, Columbia University and the Metropolitan Museum of Art in July and October 2013, teaching my 'eye-draw' method and the synchronization of eye and hand. See DVD for audio recordings of lessons.

Empirical methods

In the Drawing and Cognition Project we observed eye and hand movements during the task of drawing. Observational drawing is particularly amenable to quantitative study, as the participant generates visible outputs, in the forms of eye and hand movements and the emerging line drawn on the paper, i.e. the process and the outcome can be measured. The input, i.e. the object that is being drawn, is also visible and can be compared with the output in several analytical and descriptive ways. I began my study assisting with eye tracking tests, and then went on to conduct my own video study of Edwards' students. I also conducted an eye tracking study at Loughborough University with Michelle Fava to explore our own drawing practices (see Chapter 6 for details of exploration of motor methods of drawing, and eye control).

Video analysis

For observation of my own drawing behaviour and that of drawing students the central method was frame by frame analysis of video footage, to record timing, and spatial location of eye and hand movements, and to observe drawing in slow and fast motion. For the purpose of the study these actions in space and time were defined as the elements of drawing. To analyse temporal elements I used editing software Final Cut Pro and Adobe Premier Pro to divide action into phases of drawing and not drawing, and looking at the paper and the original. The camera used, Sony digital camcorder DSR pd150, allows the observation of location of the gaze on the paper or the original, and phases of drawing and not drawing, accurate to 1/24 of second. Hand drawn timelines also show the playing out of the process and interactions between hand and eye. To record spatial elements I used the same method of video analysis, to locate the gaze, and accuracy software to measure spatial aspects of the final drawings in comparison to originals.

I was interested in the interrelationship of temporal and spatial elements of the drawing process. For example, where does the drawer look at the beginning of drawing a line, the middle and the end? When does the drawer look at the paper and when at the original? So the questions explored were: 1) Where is the hand? 2) Where is the eye? 3) Is the hand moving? 4) Is the eye moving? 5) When is the eye moving? 6) When is the hand moving? 7) How do those elements interact?

Video playback enables precise information about when participants are drawing or pausing, and about the movements of the pencil. Slow motion allows detailed observation of drawing, as well as useful observation of actual speeds of drawing. The drawing was broken down to show phases of drawing as per the elements studied, and in terms of segmentation of the lines, with still frames exported to show the progression and number of line segments in a drawing.

Case studies of Betty Edwards' students, learning to draw

The experimental element of my study consisted of an empirical study to explore the effects of drawing practice on eye and hand movements and drawing accuracy. This involved students who were taking a 5-day observational drawing course for beginners in San Diego and Santa Barbara, California, 16th July – 21st August 2009, run by Edwards and her son Brian Bomeisler. The experiment was a within-subject study, comparing the behaviour of drawing students before and after undertaking intensive drawing training.

The distinction between my research and Tchalenko's is that I was investigating the learning process, while he was focused on the act of drawing. I wanted to investigate how accounts of changes in perception may manifest themselves. The drawing course was ideally suited for this study as students follow a model of drawing instruction that is documented in detail in Edwards' drawing manual and on a DVD, and that reflects widely-used teaching paradigms. Edwards has been teaching drawing since the 1960s, and has collected much evidence of the effects of drawing tuition on students, in the form of written accounts and 'before and after' drawings.

Edwards believes that drawers can learn a new way of looking, for drawing. Furthermore she asserts that this can be learnt quickly, either through her book or on one of her intensive 5-day courses for beginners. The question was whether this transformation, which she describes as a cognitive shift, is also evidenced in physical changes. My research looked for recordable

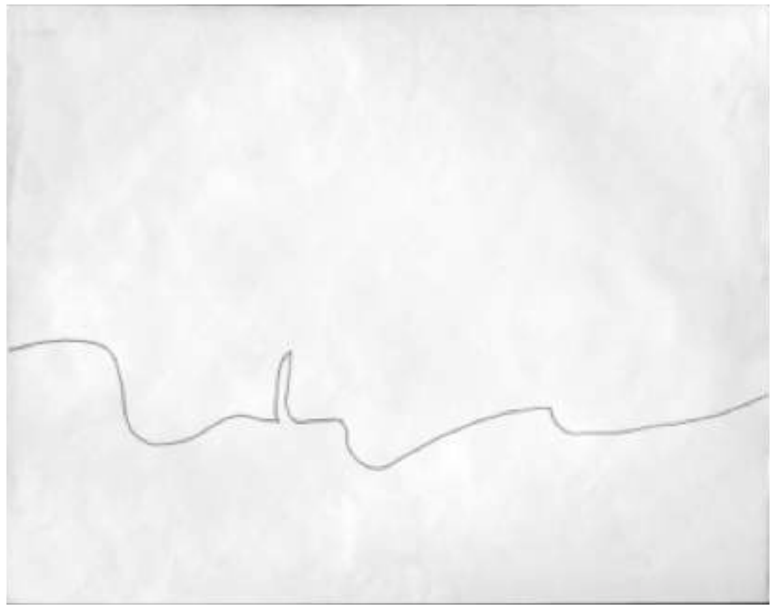


Fig. 3.15 Original line that the students copied.

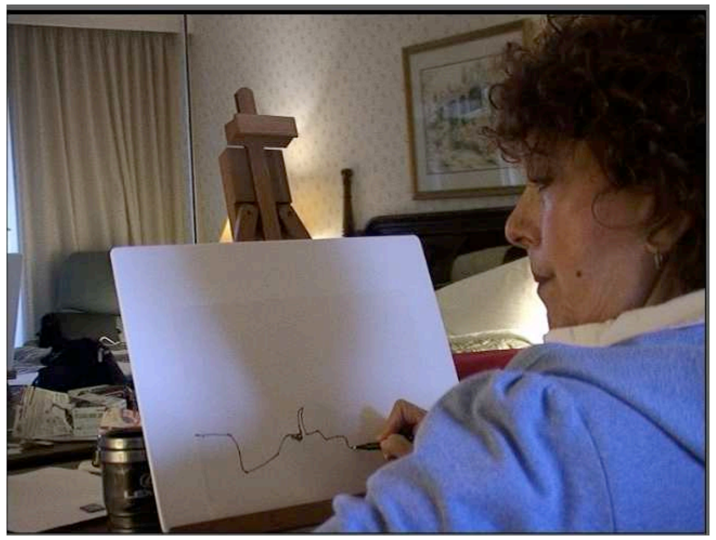


Fig. 3.16 The experimental set up.

evidence of this adaptation in the eye and hand movements of her students. The hypotheses tested were developed from Tchalenko's findings on expert drawer's hand eye interaction. Results aimed to provide new quantitative information about the processes of teaching and learning to draw, and to directly link evidence of physical behaviour with experiential accounts. I designed a longitudinal study of the learning of drawing, allowing the correlation of changes in behaviour with drawn outcomes. The results are reported in Chapter 4. Focusing on the specific case of how people copy a line drawing, I was looking for evidence of the effects of drawing practice and instruction.

Due to the intensive nature of the training course, the need to find students willing to be observed and tested, and the detailed time consuming frame by frame analysis the study was designed as case studies of three students. Video footage was supplemented by information from interviews, students' 'diaries of change' and video and audio recordings of the classes. The objective was to look for changes in patterns and rhythms of students' eye movements and in their phenomenological experience of drawing as well as in their way of drawing.

In physical terms the study asked:

Where are students looking while they draw? Are there discernible patterns in their eye movements? Do these patterns change as a result of drawing practice? Do certain patterns or types of eye movements appear to result in more accurate final drawings?

In terms of interpretation, what may these eye paths suggest about perceptual activity during drawing?

Design and procedure

The findings of Miall and Tchalenko, informed the study. Their findings suggest that, compared to a novice, an expert:

- Spends more time on the task
- Draws slower
- Pauses more, and hence produces more line segments
- Achieves a higher level of spatial accuracy in copying
- Uses a just-in-time strategy, including the use of 'blind drawing' and just-in-time glances to the paper when a segment of drawing is about to be completed

The key finding explored was the expectation of segmentation of complex lines into simple line segments and the use of pauses. Tchalenko and Miall's findings were compared with my within-subject observations of changes in eye-hand interactions of students, learning to draw. Participants were asked to copy a 2-d line drawing. The original 2-d line drawing (fig. 3.15).

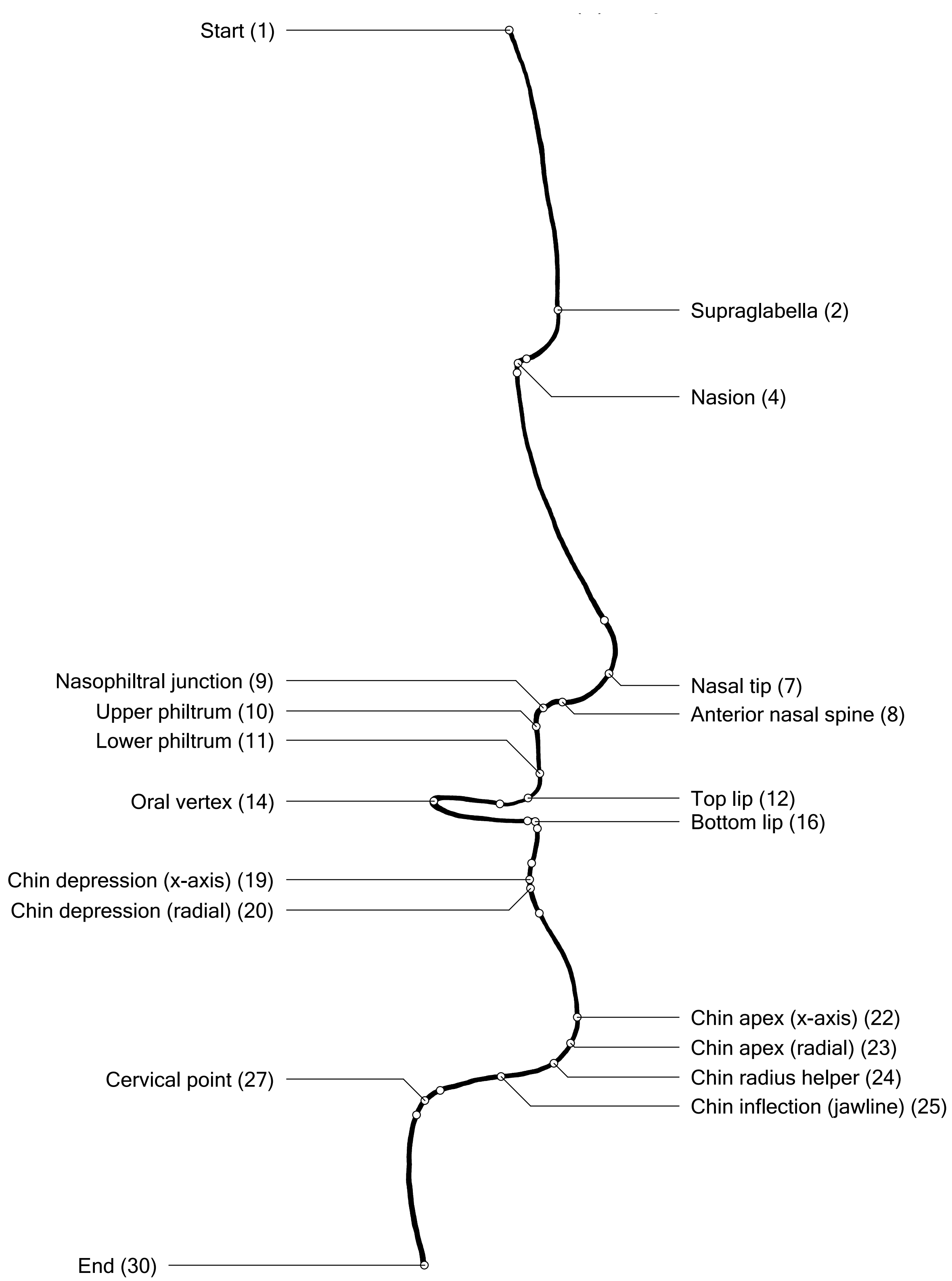


Fig. 3.17 The original line, labelled with landmarks used for accuracy analysis

was placed on an easel at 60% left of an easel with the blank sheet of paper for the copy to be drawn on (see fig 3.16). This meant that the participant needed to make a significant rotation of the head between looking at original and the paper. In this way the task was different from those in Tchalenko and Miall's copying tests, where the original was adjacent to the paper. In this study, due to questions about whether peripheral vision either while looking at the original or during saccades between original and paper may contribute to visual perception, 'blind drawing' is referred to as 'hand-alone' drawing. This means drawing when the eye is off the paper.

Video footage was analysed in terms of changes in a) spatial and temporal interaction of eye and hand (performance) and b) the line drawn (output). The study asked 'does the hand need the eye?' and if so in which situations - 'when does the hand need the eye?' Affirmative answers will then pose questions about why the hand needs the eye and whether the drawer knows, explicitly or implicitly, that the hand needs the eye, and when it needs it.

Measuring behaviour

Tchalenko's eye tracking research findings are primarily related to behaviour. His quantitative analysis of data was carried out using eye tracking software in conjunction with video footage from a scene camera. Eye tracking gives more precise data on the spatial location of fixations, which were not required here. Video was more suitable for this study, as we required binary data sets, with the eye either on or off the original, and the hand either drawing or not drawing. The video analysis carried out in this study uses a method that Tchalenko developed for analysing footage frame by frame to assess eye and hand behaviour and interaction (See Tchalenko 2009b).

Measuring accuracy

When this study was made, Tchalenko had not assessed the accuracy of participants' copies / drawings, apart from by relying on his own visual assessment. He has used computer software to analyse accuracy in his recent research. Other recent studies of observational drawing have used human judges to assess accuracy (for example Cohen 2005, Kozbelt 2001).

In order to correlate changes in behaviour with ability to draw accurately a software programme was designed, capable of comparing continuous drawn lines. The software can provide coordinates for any chosen point on a line, and can identify turning points and select landmark points for analysis (see fig. 3.17). The identification of key points to allow comparison between original and copies required substantial statistical analysis and presentation resources. Computer programmer, Dan Pope, helped to devise reliable means of determining useful landmark points, using analysis of rates of change in the angle of line. The programme also measures the line thickness, assisting identification of turning points and points where the drawer pauses.

Hypotheses

Hypotheses were designed to test the findings of Tchalenko and Miall about drawing of simple versus complex lines, and the question of when the eye needs to look at the paper for spatial accuracy. Tchalenko and Miall found that novices and experts were similarly able to accurately draw simple segments of line, but experts were more accurate when joining the segments together on the page. Applying the findings to this case, I was investigating whether beginner students achieve accuracy in shape on day 0 and day 5, but only achieve accuracy in spatial relationships of segments on day 5.

Data sought

Information was collected from 3 sources: video footage, the participants' test drawings and the participants' own accounts (in the form of interviews and diaries). Data was sought relating to:

Timing and patterns of eye and hand movements

Evidence of line segmentation

The video footage from each test recorded data from the 4 modes:

Eyes: Looking at the paper (P) / Looking at the original (O).

Hand: Drawing (D) / Not drawing (ND)

These 4 variables were reviewed in several ways, including a comparison of total time spent in each mode, interaction between modes, speed of drawing, dwell frequency, and the number of segments drawn.

Changes in pattern of eye and hand movements from day 0 to day 5 were shown in visual representations of the video timelines, for example, fig 3.18.

Participants' behaviour on day 0 was first compared with the model of expert drawing and then participants' behaviour on day 5 was compared with both the expert model and their behaviour on day 0 (i.e. within subject).

Participants' test drawings

A collection of signed, dated and labelled drawings were obtained for the purpose of analysis.

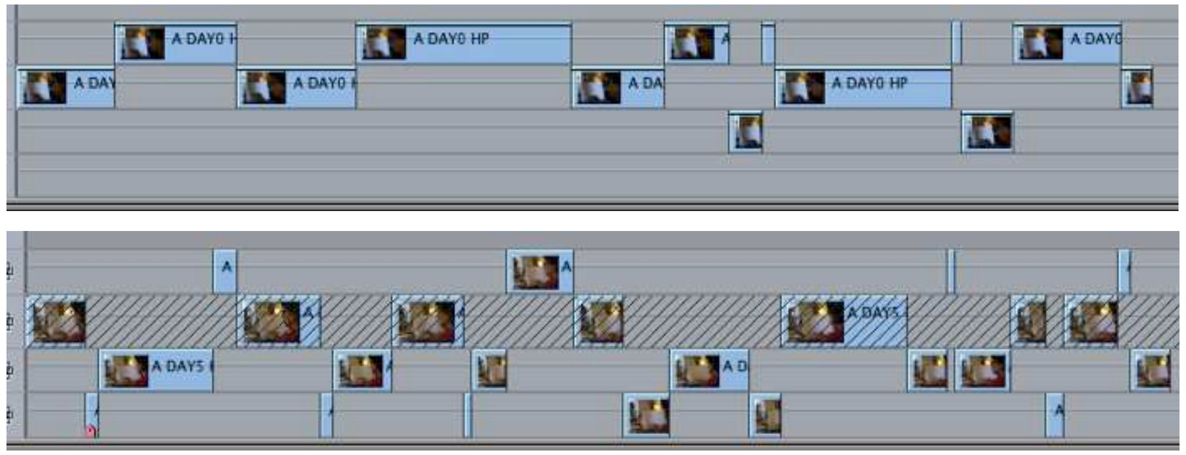


Fig. 3.18 Timelines used to analyse eye and hand movements. Participant A day 0 above, Participant A day 5 below.

The participants' copies were superimposed on the original for an initial visualisation of the accuracy of the copies. Then accuracy data was obtained using the custom-built software (Accuracy Measures AM). Data was obtained for each test measuring accuracy of a) the whole line and b) line segments, in two systems, one finding spatial coordinates for landmark points in relation to the x and y axes, and the other measuring distances along the line. The original line was a drawing by the author of a face in profile. For the experiment it was presented turned through 180 degrees, so unrecognisable as a profile. For analysis it was labelled according to the features of the profile, in order to easily identify points. During the tests the line was always presented horizontally (fig 3.16).

Metrics were chosen to enable comparison between the original and copies (fig 3.17).

Data collection / procedure

Before conducting the experiment, during the previous week, I observed Edwards' drawing course for five days, and interviewed several of her students. In the week of the experiment I took the drawing course myself, in a group of twelve students, including the three whom I was observing. In anthropological terms my role in the first week was that of 'observer' (see Bernard 2006) and in the second week of 'observing participant'. Data was collected using video and audio recording, through interviews with students and the teacher Brian Bomeisler, (Edwards' son), by keeping logs and diaries, and asking students to keep diaries.

Observation of and participation in the drawing course provided background information and a record of the training and practice of the three test participants on the course.

To augment the systematic study the entire 5-day drawing course was recorded on a digital audio recorder. The recording includes Brian Bomeisler's lectures, instructions, advice and student's comments and questions. Participants were interviewed at the end of each test, regarding how they found the task and whether they encountered particular problems with the task. In addition I reviewed Edwards' instructional DVD. This is a shortened version of the 5-day drawing course.

Interviewing

My aim was to use interviews to link conscious experiences of drawing with the data from my experiments and from cognitive science research. Eye hand movements can be interpreted in the context of what people say about drawing. The interviews tried to ascertain more about participants' drawing experience and their awareness of their intentions and strategies during the tests and in their drawing practice.

In response to working with Tchalenko, I introduced interviews with his participants in an effort to relate their experience of drawing with his physical findings. We both had questions for the participants about their drawing experience and strategies – I formalised this into a new element of his methodology, enabling the marrying of his experimental findings with accounts of his participants' conscious experience of the drawing process.

I studied emerging cognitive science techniques in the study of consciousness, with a similar interest in connecting conscious experience of action with observation of that action. Varela and Petitot (Petitot et al 1999) have developed a theoretical framework, broadly referred to as cognitive phenomenology, while Petitmengin (1999) has developed a reflective interview method to reveal aspects of the subject's experience that they were not consciously aware of. The objective is to bring new awareness of the drawing process to the participants, not just to the researchers. Notably, Petitmengin applied an intensive cognitive 'neuro-phenomenological' method in interviews with epilepsy patients, demonstrating the efficacy of this method in a very practical way; patients were found to be better able to predict seizure onset after interview sessions with Petitmengin.

I also looked at Interpretive Phenomenological Analysis, IPA (see Smith, Flowers & Larkin 2009) and began to develop interview methods to examine subject's conscious and subconscious experience of the drawing process. IPA provided a framework for development of the interview method described here. Stemming from psychology, it offers a practical method of qualitative analysis, with similar aims to those of cognitive phenomenology but with a less intensive, more useable framework for interviews. In-depth interviewing tries to encourage reflection by participants on motives and action. It is recommended for small samples and case studies. Interviewees' comments can often suggest new ideas and possible adjustments to experiment design and technique. In a similar way Tchalenko (2009b) assessed his analytical results and interpretations against a film of Matisse drawing, in the light of Matisse's own remarks about his method.

I also investigated ethnographic methods, (Bernard 2006) now commonly used in product development; people are filmed carrying out goal-oriented tasks, and then asked to watch the film with the researcher, and comment on their actions, specifically trying to remember decisions they made and their conscious rationale for their behaviour. Watching themselves in action can bring up interesting insights, and potentially, like Petitmengin's method, reveal previously subconscious awareness and reasoning. My preliminary trials of this visual ethnographic method in Tchalenko's lab suggested that it may be a very useful technique for shedding light on elements of drawing behaviour and experience. Participants are shown the test images and asked what they remember about their execution of the drawing: their starting point, decisions they made, areas they found difficult, etc. Then they are shown video footage of themselves carrying out the drawings, and asked similar questions about the process. It is interesting to compare what the subject thought they did with what they actually did. This can shed light on the subject's perception of the process and their awareness of their approach to drawing, as well as on the process itself.

Lab interviews procedure

Interviews were conducted immediately after eye tracking drawing tests in an adjacent room, recorded using a BOSS professional audio recorder. The questions asked concerned:

(i) Level of drawing experience

(ii) Execution of tasks: Their ideas about why they found specific tasks harder / easier

Participants were shown copies of the test images, and asked questions.

Owing to time restrictions, I adopted the principles informing Petitmengin's method, but conducted shorter interviews, in order to generate a manageable quantity of footage. I restricted interviews to half an hour, asking the same set of questions to each subject, in the same order.

Participants were shown the test images and asked what they remembered about their execution of the drawing: their starting point, decisions they made, areas they found difficult. These were conducted immediately after the tests.

The interviews were structured so that much of the data could be analysed and compared between participants. Analysis aimed to identify patterns between participants, and possible links with patterns in quantitative data.

3.4 Discussion

The methodology is offered as an appropriate and productive way to study the orchestration and articulation of the body for observational drawing and its role in elucidating the complex relationship between perception and action, contributions being longitudinal study methods, interdisciplinary methods, and quantitative accuracy measures. In summary, the methodology entails attention to parts and whole, using drawing and scientific experimentation. As Kandel observes, there is a place for reductionist approaches in both science and art. 'Science seeks to understand complex processes by reducing them to their essential actions and studying the interplay of these actions – and this reductionist approach extends to art as well.' (Kandel 2012 p.xvii). The methodology switches between quantitative, qualitative and reflective methods, and breaks processes into elements and then looks at the bigger picture. Drawing encompasses a wide range of practices and skill, manifested physically and cognitively.

My view, from in between domains, is that scientific research has developed some useful provisional models of the physics and cognition of observational drawing. These need further elaboration and testing, including study of learning to draw and micro-level studies of brain activity.

Chapter 4 Learning to draw

Quantitative study of changes in drawing behaviour and accuracy of students on Betty Edwards' 5-day Drawing Course

4.1 Introduction

Changes in behaviour, specifically in eye-hand interaction, were found in three novice drawing students after they undertook an intensive 5-day observational drawing course. Students were filmed and interviewed before and after training, to assess the impact of drawing practice. Findings support those of Tchalenko and Miall (2009) who identified behavioural differences between inexperienced and experienced drawers. In the present study it was found that after 5 days of drawing training and practice subjects took longer to copy the same original line drawing, looked back and forth between the original and paper more often and segmented the drawing into more, and shorter, line segments. Segmentation, which is suggested by Tchalenko and Miall to be a key to accurate drawing, occurred more on day 5 than on day 0 of training. Students paused more and for longer. Tchalenko has reported what he has called 'drawing blind'; drawing while eyes were on the original, not the paper. This raises interesting questions about when blind drawing may be an appropriate hand-eye strategy, when used in conjunction with a strategy to monitor the emerging drawing on the paper. Blind drawing undertaken by participants in this case study raises questions about when the drawer needs to look at the paper, and challenges the conventional view that drawing relies on visual memory and a transfer of snapshots of visual information from the eye and memory to the paper. A detailed frame-by-frame temporal analysis of video footage revealed that participant A developed a distinctive eye-hand interaction sequence, similar to Tchalenko's model of expert copying behaviour. This temporal profile of eye and hand interaction emerged as the most interesting data generated by the study, leading to findings that suggest a fine-tuning of phases of drawing and pausing, and of gazes between original and paper. This led to the development of a model for exploration in the drawing studio, which is detailed in Chapters 5 and 6. A drawing instruction method was created, informed by these questions and findings, and explored in drawing lessons, and in relation to recent cognitive findings about the role of hand in perception.

As noted in the methodology (Chapter 3) software was designed to analyse accuracy of the copies. In all three cases, accuracy improved by day 5. Notably, when comparing the length of participants' copied lines with the original line, participant A achieved 100% accuracy (to the nearest 0.1mm) on day 5.

In addition to providing data and findings from the three case studies, the research represents a first step in developing useful longitudinal methods to track behavioural and perceptual changes relating to observational drawing practice.

4.2 Summary of findings from recent drawing research

The methodology for this quantitative study is outlined in the previous chapter. As explained, the study built on Tchalenko's findings about novice and expert drawing behaviour, and sought to determine whether practice and/or training will yield behaviour supporting his expert profile. The focus on movements and temporal and spatial interaction was in line with the direction of the emerging focus of the thesis, that of exploring observable action rather than cognitive effects and strategies.

Based on their studies, Tchalenko and Miall developed two hypotheses relating to expert drawing behaviour:

1) A segmentation strategy is adopted by more experienced drawers, wherein they draw short lengths of lines and systematically build them up into a drawing.

2) Drawers encode segments 'to-be-drawn' into motor plans, rather than visually capturing segments and then drawing them from visual memory.

The first of these findings, and Cohen's claim that more experienced drawers 'look little, look often' (Cohen 2005), provided the basis of the hypotheses explored in the study described here. The second finding is considered in chapters 5 and 6, in the light of these case studies.

4.3 Hypotheses

By day 5, and compared to day 0, the following changes will occur:

Times

1) The time (T) spent on the task will have increased

2) The time spent drawing (D) will have increased

3) The time spent not drawing (ND) will have increased

4) The proportion of time spent not drawing (ND/T) will have increased

Participant		K	N	A	K	N	A
Day		Day 0	Day 0	Day 0	Day 5	Day 5	Day 5
T	Total time	9.36	10.80	27.68	45.48	24.80	39.44
D	Time drawing	7.44	8.80	19.96	18.12	18.88	22.56
ND	Time not drawing	1.92	2.009	7.72	27.36	5.92	16.88
O	Eye on original	4.96	7.76	14.72	23.20	14.88	18.96
P	Eye on paper	4.40	3.04	12.96	22.28	9.92	20.48
Do	Drawing, eye on original	38.84	5.96	10.52	3.68	9.68	8.20
Dp	Drawing, eye on paper	3.60	2.84	9.44	14.44	9.20	14.36

Fig. 4.1 Times for 3 participants K, N & A (in seconds)

Participant		K		N		A	
Day		Day 0	Day 5	Day 0	Day 5	Day 0	Day 5
DW o	Dwells on O	3	11	5	10	11	12
DW p	Dwells on P	4	9	5	11	12	13
L	Number of segments drawn	3	10	4	6	9	15

Fig. 4.2 Numbers of dwells on original and paper and numbers of line segments drawn for 3 participants K, N & A

					Hypothesis		Hypothesis supported y / n		
Participant		K	N	A			K	N	A
T	Total time spent	486%	230%	142%	1	Increase	y	y	y
D	Time spent drawing	244%	215%	113%	2	Increase	y	y	y
ND	Total time spent not drawing (pausing)	1425%	296%	219%	3	Increase	y	y	y
ND/T	Proportion of time spent not drawing	286%	126%	154%	4	Increase	y	y	y
D/T	Proportion of time spent drawing	51%	94%	79%					

Fig. 4.3 Within subject changes in times spent drawing and not drawing, day5 in relation to day0 for 3 participants K, N & A

Participant		K	N	A	K	N	A
Day		Day 0	Day 0	Day 0	Day 5	Day 5	Day 5
D/T	Proportion of time spent drawing	0.79	0.81	0.72	0.40	0.76	0.57
ND/T	Proportion of time spent not drawing	0.21	0.19	0.28	0.60	0.24	0.43
Do/O	Drawing, eye on original as proportion of time with eye on original	0.77	0.77	0.71	0.16	0.65	0.43
Dp/P	Drawing, eye on paper as proportion of time with eye on paper	0.82	0.93	0.73	0.65	0.93	0.70
Do/T	Drawing, eye on original as proportion of total time	0.41	0.55	0.38	0.08	0.39	0.21
Do/D	Drawing, eye on original as proportion of time drawing	0.52	0.68	0.53	0.20	0.51	0.36
Dp/D	Drawing, eye on paper as proportion of time drawing	0.48	0.32	0.47	0.80	0.49	0.64
O/T	Eye on original as proportion of total time	0.53	0.72	0.53	0.51	0.60	0.48
P/T	Eye on paper as proportion of total time	0.47	0.28	0.47	0.49	0.40	0.52

Fig. 4.4 Relational data for 3 participants K, N & A

Line segments

5) line segment number (L) will increase (Participants will draw shorter line segments).

Rhythm and frequency

6) The number of dwells (continuous gaze) on original and paper will increase

Accuracy

7) Accuracy of shape of simple line segments will not improve

8) Accuracy of angles between simple segments of line will improve

If so:

8a) Participants will achieve accuracy of shape of segments both on day 0 and day 5.

8b) Participants will achieve a higher level of relational accuracy of segments on day 5 compared to day 0.

There was also the question of whether participants' behaviour would fit with findings of Tchalenko in the different situation of 'drawing at a distance' (i.e. the orginal and drawing were located a distance from one another, requiring participant to turn their head in order to switch their gaze between original and their drawing) and, if so, whether any changes would be observed between day 0 to day 5 indicative of a new approach to the problem of accurate copying and drawing.

4.4 Results

The following results are for participants K, N and A.

4.4.1 Summary of findings

Results supported all the hypotheses of predicted changes. See fig 4.3.

All three participants took longer on day 5 than day 0 to copy the original line drawing, or comparable sections of the drawing. See fig. 4.1. Most notably, participant K took 9.36 seconds on day 0 and 45.48 seconds on day 5. In all cases there was an increase in the time spent not drawing (ND), and in the proportion of time spent not drawing (ND/T), the most extreme case being K, whose proportion of time spent not drawing increased by 286%.

All looked back and forth between the original and paper more times. For example, K looked at the original only 3 times on day 0, and 11 times on day 5.

They all broke up the drawing into more, and shorter, line segments. For example, participant A drew 15 segments on day 5 compared with 9 on day 0. See fig 4.2.

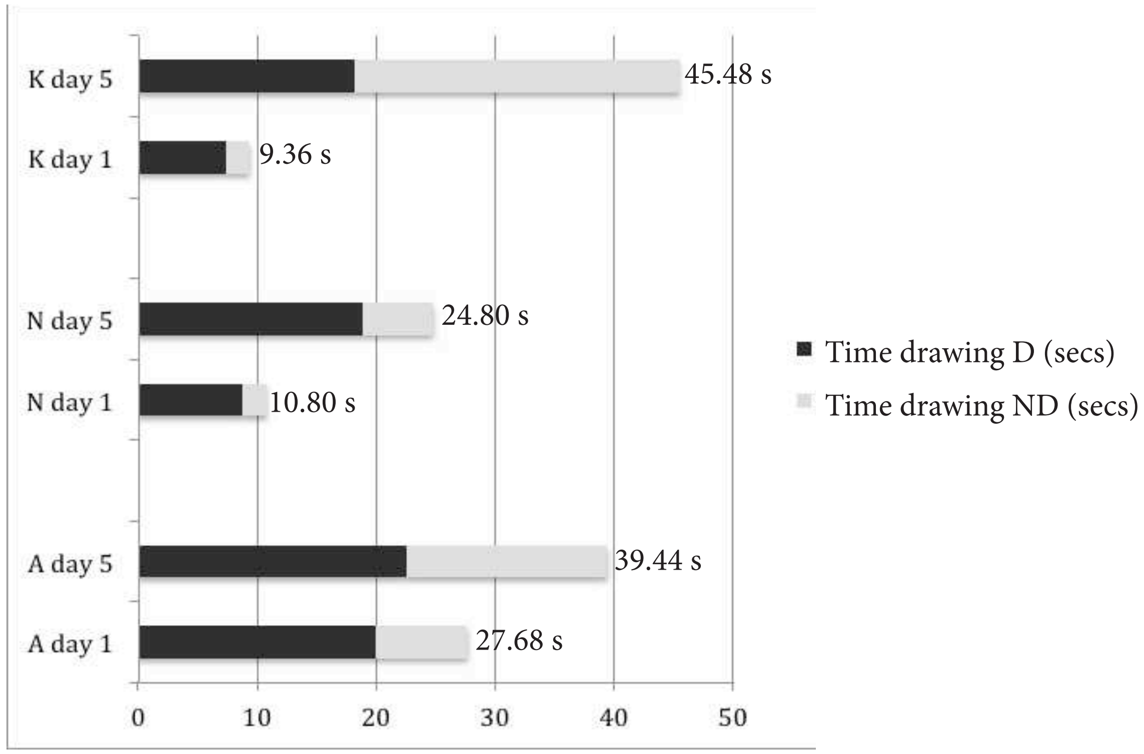


Fig. 4.5. Total time drawing D and not drawing ND for participants K, N & A

Line		Original	Copy by A	Copy by A	Copy by K	Copy by K	Copy by N	Copy by N
			Day 0	Day 5	Day 0	Day 5	Day 0	Day 5
	Length of line in mms	435.50	519.48	435.50	521.30	465.66	602.94	523.64

Fig. 4.6 Accuracy measures. Length of lines in mms. of the original and of participants' copies on day 0 and day 5.

In the three cases accuracy improved by day 5. See fig 4.6. Comparing the length of copied lines with the original line, participant A achieved 100% accuracy, to nearest 0.01mm, on day 5 with the length being the same as the original, 435.50mm. On day 0 participant A's copy measured 519.48mm. They all paused more often and for longer. See fig. 4.3.

Interestingly, participants A and K both changed their eye hand behaviour more and their accuracy improved more than participant N. From observation of the superimposed copies (fig. 4.7) N's copy on day 5 appears more similar to her own copy on day 0 than to the original. Her dwell numbers increased but she only drew 6 line segments on day 5 compared to 4 segments on day 0. Therefore the results support the hypothesis that segmenting the line into more segments may be a key strategy for accuracy.

4.4.2 Temporal

Time Drawing / Not Drawing (Pausing)

See figs. 4.1. & 4.5.

Total task time (T), time spent drawing (D) and time spent not drawing (ND) increased in all participants (hypotheses 1, 2 and 3).

In all cases the proportion of time spent not drawing (ND/T) increased, most extreme being K, where the increase was 286% (hypotheses 2, 3 and 4).

Rhythm

There were increases in number of dwells on original and paper in all cases, although only by 1 dwell in participant A. See fig. 4.2. (hypothesis 6).

4.4.3 Spatial

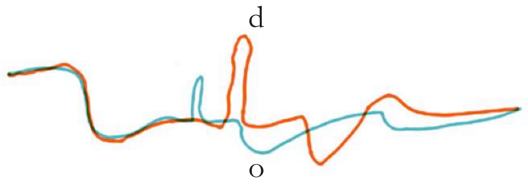
Segmentation

See fig 4.2. All participants broke the drawing up into more, and shorter, line segments (L) (hypothesis 5).

Accuracy measures

See fig. 4.6. All participants significantly improved accuracy of line length on day 5, with N improving the least.

It should be noted that the original line began and ended at the end of the sheet of paper, so it is not surprising that the participant's lines matched the original in terms of x coordinates on the page.



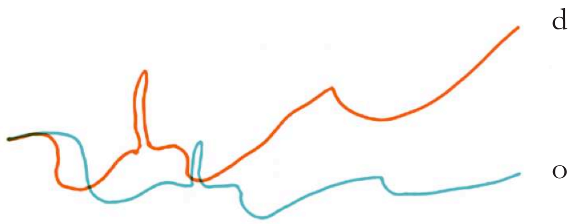
A day 0

A day 5

K day 0

K day 5

N day 0



N day 5

Fig. 4.7.Accuracy measuring. The participants' drawings (d) superimposed on original (o)

Hypothesis 7, that accuracy of shape of simple line segments will not improve, was not assessable, as it was not possible to identify line segments within the original and drawings to compare.

See appendices 4(a) to 4(o) for details of computational analysis of accuracy of line proportions between selected points on the line.

4.4.4 Relationships between temporal and spatial behaviour

Blind drawing

See fig 4.4. Blind drawing (Do) decreased as a proportion of total time spent Do/T, and of time spent drawing Do/D for all participants. K's method changed dramatically: the proportion of blind drawing in relation to the total time spent dropping from 0.41% to 0.08% from day 0 to day 5, and as a proportion of time spent drawing from 0.52% to 20% day 0 to day 5.. However for N the proportion of blind drawing remained high. Tchalenko's recent findings (Tchalenko et al. 2014 in press), suggest that blind drawing is a strategy frequently used by expert drawers, especially when drawing from life and for more complex images.

Rhythm

See fig. 4.2.

The number of dwells on the paper and the original show that all participants looked at the original more times and looked back and forth between the original and paper more times, in support of Cohen's 'look often' finding (2005) (hypothesis 7) .

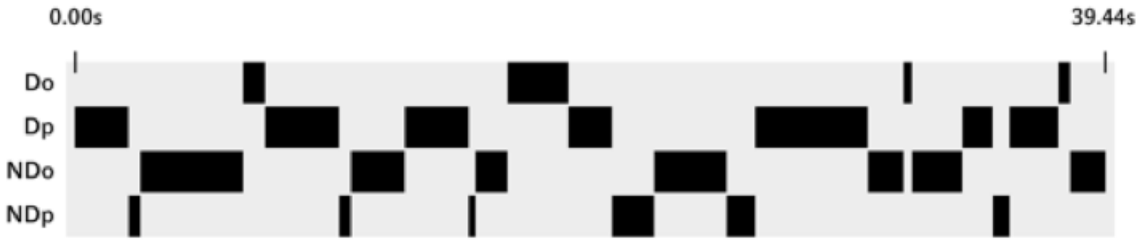
Participant A case study

See figs. 4.8 & 4.9. See appendices 4(r) and 4(s) for the original video footage of participant A on day 0 and day 5.

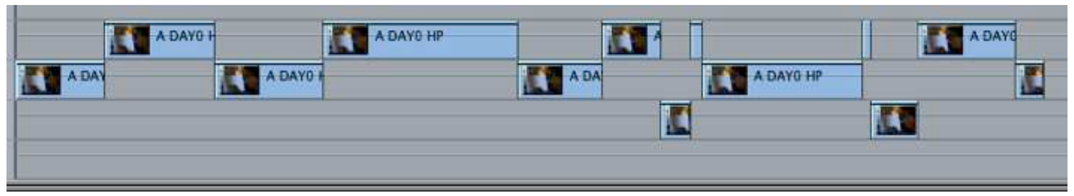
Detailed frame-by-frame observational analysis of the video footage was made for particpant A. A was chosen for this stage of study as despite some aspects of the data analysis revealing little change (for example, the number of dwells only increased by 1 on day 5) reviewing the timeline for patterns of interaction revealed marked differences in temporal sequences of drawing, not drawing, looking from original to paper. On day 5 A can be seen to be pausing more, and for longer between phases of drawing. The mean time drawing per line segment decreased by 33%, from 2.22s to 1.50s. The number of segments drawn increased from 9 to 15.

At the same point on day 0 and day 5 A's pen got stuck to the page. This led to extra long

Participant A day 0



Participant A day 5



Participant A day 0

Participant A day 5

Fig.4.8 Timelines showing video editing into 4 behaviours: Do, drawing while eye on original; Dp, drawing while eye paper; NDo, not drawing while eye on original; NDp, not not drawing while eye on drawing while eye on original, for participant A day 0 and day 5.

pauses at these points, after line segments 3 and 8 on day 0 and day 5 respectively. With the data adjusted to remove these respective 'stuck' pauses (i.e. for day 0: 7.72s-4.8s, for day 5: 16.88-3.72) A's mean length of pause on day 0 was 0.42s and on day 5 was 1.01s.

A pause was defined as 6 video frames (0.24 seconds) without drawing. A's pauses were shorter on day 0 than on day 5, giving the impression on day 0 of continuous drawing when viewed in real time in the video footage. Pauses were identified on the drawings by ink spots where the pen paused. However when the data was recalibrated to define a pause as ½ secomd rather than ¼ second, for A day 0 had only 3 line segments and only 2 pauses, one of which was when the pen stuck on the paper for approximately 4 ½ seconds. day 5, under this definition, had 11 segments and 10 pauses.

For A on day 5 a pattern of drawing and then pausing was identifiable from the video footage and timelines, and represented a distinct change from what was happening on day 0. From observation of the video A's pausing behaviour was observed to be markedly different, with pauses divided between times looking at the paper and original, and spaced between phases of drawing.

4.5 Discussion

Changes in behaviour

The results, which support all the hypotheses, indicate that significant changes in behaviour occurred in all the participants, after only 5 days of training and practice. These changes fit with Tchalenko and Miall's findings reported at the time of design of this study (but see below for subsequent findings), thus demonstrating replication for a condition where this copying involves moving from one field of view to another. All the students wrote in their diaries that they were 'seeing things differently', some going into more detail about exactly how this manifested itself. The results from this study suggest that the students took a first step towards acquiring a particular way of looking, for drawing.

Changes occurred in the number of dwells on the paper and original, the number of line segments drawn, time spent drawing, time spent not drawing, time spent with eye on original and eye on paper, slower drawing speeds, and in accuracy of copying.

What these changes mean

The largest changes were in total times spent drawing and not drawing. Another crucial

	DAY0				DAY5				
	Timecode (in secs)	Timecode (in secs)	Duration (in secs)	Duration (in secs)	Timecode (in secs)	Timecode (in secs)	Duration (in secs)	Duration (in secs)	
LINE									
Segment number	start time	end time	drawing	pause	start time	end time	drawing	pause	
1	0	6.12	6.12	0.28	0	0.88	0.88	1.92	
2	6.4	8.12	1.72	0.44	2.8	4.4	1.6	1.08	
3	8.56	9.76	1.2	4.8	5.48	6.56	1.08	0.64	
4	14.56	18.2	3.64	0.76	7.2	8.96	1.76	2.36	
5	18.96	20.68	1.72	0.28	11.32	13.2	1.88	0.6	
6	20.96	22.44	1.48	0.28	13.8	13.92	0.12	0.84	
7	22.72	24.2	1.48	0.44	14.76	15.28	0.52	0.28	
8	24.64	25.16	0.52	0.44	15.56	16.56	1	3.72	
9	25.6	27.68	2.08		20.28	20.96	0.68	0.52	
10					21.48	22.08	0.6	0.36	
11					22.44	24.32	1.88	2.04	
12					26.36	27.92	1.56	0.76	
13					28.68	29.68	1	1.08	
14					30.76	36.32	5.56	0.68	
15					37	39.44	2.44		
			19.96	7.72			22.56	16.88	total
			2.22	0.97			1.504	1.21	mean
				2.92				13.16	adjusted total *
				0.42				1.01	adjusted mean **

* total time minus pause no. 3 (4.8 secs) for day0 and pause no. 8 (3.72 secs) for day5
** mean time calculated from adjusted total

Fig. 4.9 Participant A. Data from frame-by-frame analysis of video footage of start and end point of each line segment drawn, and of start and end point of each pause.

element seems to be the temporal rhythm and interaction between phases of eye and hand movement and between drawing and pausing; time spent looking at the original and the paper are organised in cycles with the drawing action. Participant A's data revealed details of these temporal aspects, notably the punctuation of drawing with frequent pauses. These more hidden changes in approach may be the most significant in terms of improvement in drawing skill. These insights informed the development of a teaching method based on training students to move in this way, supported by verbal explanations about visuomotor processes and information about what experts do differently in order to draw accurately. Chapter 6 describes this development, and how these findings contributed to a practical scientifically-informed drawing method.

The results show similar ratios on day 0 and day 5 between looking at the original and the paper. This finding can not be compared with Tchalenko's findings, as here participants were allowed to correct lines as they drew. This may have led them to look back and forth more between the original and paper to check drawn lines, and consequently more transitions between paper and original, compared with Tchalenko's participants. This means that glances to the original cannot be assumed to be capturing visual information about the next line segment to be drawn. The method does not provide information on the function of fixations so at this stage we do not know why the participants were looking at object or paper. It is possible that their behaviour had changed by day 5 and that glances to the paper and original served different purposes, for example to assess and compare lines. See Chapter 6 for consideration of assessment and feedback processes, and for further discussion of the role of 'hand alone' / blind drawing.

The role of pausing and segmentation

One of the main changes was increased segmentation, i.e. drawing shorter segments of lines. A's approach changed from using almost continuous drawing on day 0 to pausing for longer between segments on day 5.

All participants paused more in total during the execution of the drawing. This finding is of interest, offering suggestions of how rhythm, timing and synchronisation may facilitate accuracy. During pausing the participants look at the original and the paper. The total amount of time spent pausing may represent more time to plan and assess the drawing, significantly contributing to accuracy, however it is not possible to ascertain why the participants are pausing i.e. the role of the pause. Participants may have had an extraneous reason for

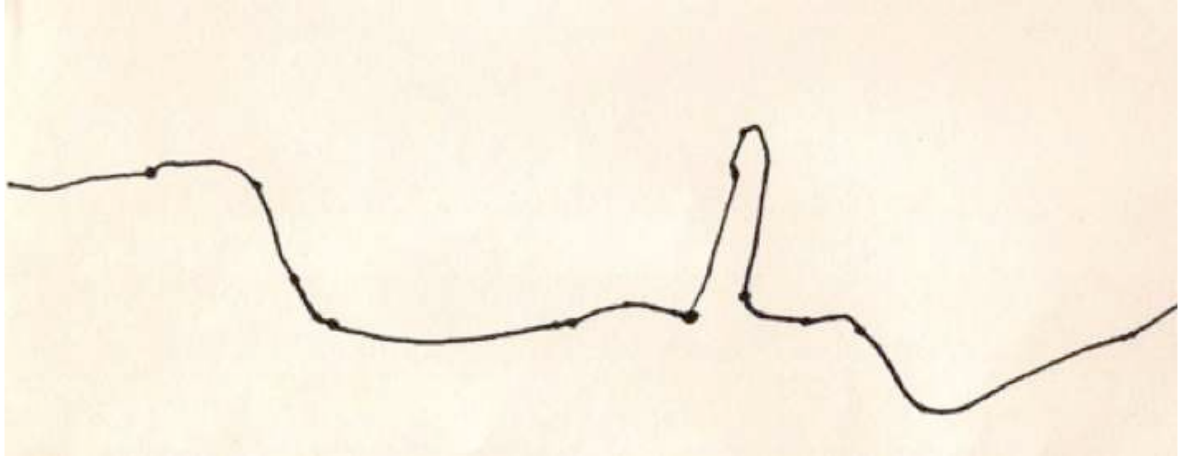


Fig. 4.10 Drawing by participant A on day 5 - ink pools reveal pauses in drawing action

pausing, which may be unrelated to the overall 'goal' of the behaviour. We cannot know from these findings what is happening cognitively during the pauses, but we can relate the data to Tchalenko's findings, where experts begin to develop gaze rhythms with longer pauses between drawing phases. The development of longer pauses prompts questions about cognitive activity during pauses, and the interaction between drawing, pausing, planning, executing and assessing. These are further explored in the next chapters, with the development of a drawing instruction that separates executive (drawing) and assessment (pausing) phases of drawing, and could be used for future quantitative study of the drawing process.

Accuracy

Results from the analysis of drawing accuracy suggest that all participants improved in accuracy in terms of spatial position of the line on the page, the length of the line, and within the line itself, i.e. internal proportions. See appendices 4(a) to 4(o). However at this stage it was hard to ascertain levels of improvement from analysis of the angles between segments. Firstly it proved difficult to locate comparable line segments within the copies and the original, and angles of lines were hard to assess as there was much variation within each segment. There were no findings to suggest that accuracy of angles on the page improved overall by day 5.

The role of blind drawing

Since this research was carried out, in July 2009, Tchalenko has explored blind drawing further, and his findings suggest that blind drawing, previously thought to be an indicator of lack of drawing experience (Tchalenko et al. 2014 in press), is in fact often an expert strategy, used more for more complex originals/subject matter. His findings up to July 2009 had not suggested that an increased amount of blind drawing signified expertise. Although the accuracy measures show that A and K improved their accuracy significantly, it remains to be determined how and why particular changes of behaviour may affect accuracy of drawing. In this test case, the copying of a complex single continuous line, a proportion of blind drawing may be an appropriate method. All of the participants employed this strategy both on day 0 and day 5, although blind drawing decreased as a proportion of time drawing for A and K, Participant N continued to use a high proportion of blind drawing on day 5. As explained, this finding prompted further exploration in the drawing studio of blind drawing as an appropriate strategy.

Tchalenko suggests that increased blind drawing by experts in more complex drawing tasks may be due to the cognitive requirement to 'find lines' in real life complex scene, meaning that

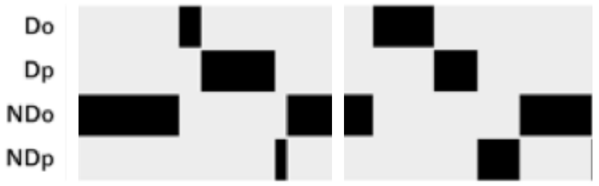


Fig. 4.11 Participant A. Pattern of dwells on day 5. NDo Do Dp NDp NDo

					Change day 5				
		K	N	A			K	N	A
P/T	Eye on paper as proportion of total time	104%	143%	111%		Increase	y	y	y
O/T	Eye on original as proportion of total time	96%	83%	91%		Decrease	y	y	y
Do/T	Drawing, eye on original as proportion of total time	20%	71%	55%		Decrease	y	y	y
Do/D	Drawing, eye on original as proportion of time drawing	38%	75%	68%		Decrease	y	y	y
Dp/D	Drawing, eye on paper as proportion of time drawing	167%	153%	136%		Increase	y	y	y
Do/O	Drawing, eye on original as proportion of time with eye on original	21%	84%	61%		Decrease	y	y	y
Dp/P	Drawing, eye on paper as proportion of time with eye on paper	79%	100%	96%		Increase	n	n	n
O	Eye on original	468%	192%	129%		Increase	y	y	y
P	Eye on paper	506%	326%	158%		Increase	y	y	y
Do	Drawing, eye on original	96%	162%	78%		Increase	n	y	n
Dp	Drawing, eye on paper	401%	324%	152%		Increase	y	y	y

Fig. 4.12. Further relational data, showing changes from day 5 in relation to day 0, for 3 subjects K, N & A

more time must be spent analysing the original. This may entail 'locking' the eye onto a line one has chosen, and keeping one's eye on it while drawing. The argument is paradoxical in one way, as it is argued that one has to keep one's eye on a line that perhaps doesn't exist! However it can be argued that this is all the more necessary because the line is elusive and may be lost if the observer takes their eye off it. These lines may be subtle demarcations of light and shade, and object contours.

Within a Do Dp NDp NDo model (draw blind, draw with eye on paper, pause while looking at the paper, pause while looking at the original) the drawer will only move the eye to the paper once the line is almost drawn, in order to monitor its end point on the paper. While all participants used blind drawing on day 0 and day 5, the differences seem to be that on day 5 A and K combined Do, blind drawing, with phases of ND, not drawing, and began to synchronise Do, blind drawing, with Dp, drawing while looking at the paper.

On a couple of occassions A adopts a sequence of fixation types close to the expert model, with some blind drawing, followed immediately by a phase of drawing while looking at the paper, and then followed by a phase of not drawing, a pause, for example Do Dp NDo, or NDo Do Dp NDp.. The pattern NDo, Do, Dp NDp entails 1) Looking at the original before starting to draw a segment NDo 2) Drawing blind Do 3) Shifting the gaze to the paper to complete the line segment Dp 4) Reviewing the line on the paper NDp (see fig 4.11).

The emerging model is that accurate drawing depends on coordination of several temporal aspects, particularly knowledge of when it is necessary to look at the paper.

Feedback, critical assessment

While gazes to the paper may not be necessary during drawing, they are essential for critical assessment of lines executed. Tchalenko's participants were generally instructed not to correct errors. This means that his participants were tested on a particular, arguably non-typical, drawing task. In this case the participants may look less at the paper, because the assessment element is omitted, which is likely to entail looking back and forth between the original and paper to compare lines. This raises an important question about the role of comparison and trial and error in the drawing process, and how Gregory's theory about trial and error and the hypothetical nature of vision explains the observational drawing process. Unlike musical performance, many styles of drawing rely on the opportunity to correct errors as one goes along, by comparing the line being produced with the original. The skill to spot and correct errors may be a significant factor in the ability to draw accurately. In this study, in an attempt to record the participant's drawing as naturally as possible, participants were permitted to correct. However drawing with felt pen restricted them to corrections by addition. During the 5 day drawing course they had been able to correct by subtraction, using an eraser. K's final drawing on day 5 and video footage show evidence that correcting played a role in her attempt at accuracy. Improved accuracy levels may be the result of improved checking and comparison mechanisms.

4.6 Comments on method

An interesting element of this study is that Tchalenko and I went on from here to conduct our research independently, using different methodologies. After this quantitative study I moved to a phase of reflective practice, and the development of teaching practices to explore and implement his and my findings about movements of drawing and eye hand interactions. My hypothesis was that hand-alone drawing may be an effective strategy, if Tchalenko and Miall were correct that the eye did not need to look at the paper for accuracy of shape. This led to the idea that the eye only needed to look at the paper at the beginning and end of each line segment, hence my supposition was that a new pedagogic model could be developed using a high proportion of blind drawing. At this point this was based on reasoning rather than scientific findings, including the findings presented here. However if, as Tchalenko and Miall had found, simple lines could be drawn accurately without looking at the paper, then with the addition of a way to link simple segments observational drawing could be successfully executed with a reduced amount of dwell time on the paper. The findings from this Betty Edwards study that were the most conclusive were the behavioural measures relating to timing and synchronisation of phases of drawing and pausing, the numbers of line segments and numbers of dwells. Findings from case study A revealed temporal aspects of drawing production.

Limitations of the study

Eye location data was subject to errors to the degree of 3 frames, i.e. 0.125 s. This is due to the filming method using only one camera, and the estimation of saccade times based on sample video footage of the participants' eyes. In order to obtain more accurate data relating to the timing of the location of the eye it would be necessary to use a second camera to film the eyes directly, to be analysed in synchronisation with footage of the hand drawing.

The behavioural results were easier to interpret than the accuracy results. The experiment was designed primarily to observe behaviour, in order to relate findings to those of Tchalenko and Miall. The accuracy measure of line length was conclusive and clear, however attempts to measure the angles of line segments and to compare shapes of line segments proved problematic. The factors affecting this were the complexity of the line, the problem of distinguishing comparable segments in the original and copies, and the variation of angles within selected segments.

The question remains of why students' accuracy improved with training and/or practice. Of the twelve behavioural factors examined in the hypotheses we cannot know which affected accuracy. The observational case studies do not isolate variables within the process, so although all participants changed their behaviour and their overall accuracy improved, we do not know what led to these changes. The first unanswered question is whether and how the drawing instruction affected the participants, as distinct from the drawing practice itself. If the same group of students had not had an instructor present but had spent 5 days practising observational drawing would their behaviour and accuracy have changed, and to what degree? My impression is that 5 days of drawing instruction had impacted on their ability to copy a 2–d line accurately, however further controlled experimentation is needed to explore what accounts for these changes. This study represents a preliminary investigation of the impact of drawing practice, and an introduction of longitudinal method supported by quantitative accuracy measures.

Future study

The findings relating to synchronisation of phases of drawing and pausing, and the sequence and rhythm of cycles of looking, drawing and pausing prompted further exploration in the drawing studio, as detailed in the next chapter. These temporal aspects of eye and hand interaction emerged as the most interesting aspect of the study. While here all the students paused more in total, the timing of these pauses within a sequence of eye and hand movements is of particular interest. Further research will look at sequences of behaviour, to explore whether experience leads to a regular pattern of use of the 4 identified modes Do, Dp, NDp, NDo, and how this can be applied in teaching of observational drawing.

Chapter 5 An enactive model for observational drawing

5.1 Introduction

Subject and aims of the chapter

This chapter proposes a theoretical basis for observational drawing, in the light of enactive theory, recent empirical findings from cognitive science, including the Drawing and Cognition Project (DCP), and Gregory's model of visual perception. These theories provided crucial elements for a characterisation of observational drawing that prioritises movement and incorporates my findings about the development of drawing movements, pausing and segmentation from the Betty Edwards' study, presented in Chapter 4. Hence, findings are combined with theory to offer a framework for the development of a practical motor model of observational drawing in Chapter 6.

The framework entails:

That the eye and hand converse, and mutually contribute to perception.

In order to allow a deep conversation between eye and hand the drawer needs to pause and allow the eye and hand to listen to one another.

The framework is based on the key perspectives:

Drawing for discovery, not depiction: drawing can be open-ended, contingent, searching, rather than capturing and depictive.

That everyday ocular vision is contingent and underdetermined, and not sufficient for drawing.

As Ingold's book title *Being Alive* suggests, drawing can develop into a way of life, an open-ended approach, of living the line, of being present, rather than a way to re present. Ingold states '…the drawn line can unfold in a way that responds to its immediate spatial and temporal milieu, having regard for its own continuation rather than for the totality of the composition.' (Ingold 2011 p.220). Writing of the gesture and act of drawing, Bryson (2003 p.150) proposed that drawing has a local logic, as contrasted with an overall compositional logic of painting.

We have seen that an input-output model is insufficient to describe or explain the complex process of drawing from life. The enactive view leads us to question the accepted paradigm that looking precedes drawing, and that the eye leads the hand. Two distinct questions arise, firstly concerning the nature of perceptual processes underlying drawing, and secondly the question of how knowledge of these perceptual processes can contribute to drawing practice and teaching. The aim of this chapter is to define drawing as a reflective multi-sensory way of perceiving. The following chapter will explore the implications of this for practice and teaching. Drawing is positioned as a perceptual process, akin to Gregory's contingent explorative model of vision, wherein the hand augments underdetermined ocular vision to enable the appreciation and articulation of finely detailed information.

Tchalenko shifted the focus from the conventional view that the eye holds the key to observational drawing, by looking at eye and hand interaction. The proposition is that these findings can be usefully applied to pedagogy, in tandem with further elements that consider feedback processes, to develop a more comprehensive practical drawing method.

We need to look at what is particular about drawing in terms of reflection, how hand behaviour affects visual perception and the conversation between eye and hand. Tchalenko asked 'when does the hand need the eye?' i.e. when does the hand need the eye as guide or monitor. From the enactive view developed here the new question is when does the eye need the hand, and the proposed answer is that the hand helps to capture and elucidate fine detail, and in Gregory's terminology, test visual hypotheses. Each drawn line becomes a contingent idea, to be tested by the eye and hand together.

The chapter develops threads of argument introduced in Chapter 2 concerning sensorimotor skills, our physical control of perception and eye hand communication, and considers specifically how Noë 's enactive theory and Ingold's view of the line apply to observational drawing. The chapter asks questions about physical behaviour and the location of perception, designed to shed light on the complex nuanced relationships between the hand, the eye, the mind and to help frame the further question of how drawing practice affects perception, for practical and empirical investigation. Exploration of this set of questions and paradigms progresses from the intelligent eyes of Alberti and Da Vinci, to Ruskin's sharpening of perception by the pencil and finally to the drawing body of Gallagher (2005), Ingold (2007, 2011) and Noë (2004), offering a multi-modal enactive view of the intertwining of the eye, hand, perception and action.

Active Vision theory (Findlay and Gilchrist 2003) and Gregory's view of vision as hypothesis testing (1997) support the argument, with Noë 's enactive theory providing a meaningful framework for the movements of drawing. This prepares the ground for practical investigation, outlined in chapter 6, of how drawing can play out through eye and hand movements in time and space.

Chapter 2 considered a range of views about the keys to accuracy in observational drawing, and showed that there is broad consensus about the need for a special way of 'looking'. However the hand has been side-lined in theories of observational drawing for over half a millennium. The enactive model of the drawing process proposed here challenges long-held views that prioritise a narrowly defined, isolated and disembodied vision. As we also saw in Chapter 2 evidence of greater eye control and fine-grained movement in observational drawers suggest that the eye develops 'drawing' skill. Scientific findings about eye hand interaction, including those from this study, suggest that the hand informs the eye, and that a question and answer process develops between them.

This leads to the argument that the hand and the drawn line contribute to visual perception, by answering questions asked by the eye. A central point is that the hand can move more smoothly and explore objects in a more detailed way than the eye.

The importance of the research is that it poses new ideas about the relationship between sense and action, by approaching the questions of observational drawing from the perspective of a practitioner and in terms of physics rather than cognition.

Finally the discussion touches on the question of the role of non-movement, pauses between phases of drawing, and the implications of the stillness of the head and body, demanded by observational drawing. In sum, the central point made is that observational drawing cannot be adequately modeled as a perception to action skill.

The special case of observational drawing

The dynamic way that the percept changes during drawing implies that one is not drawing from perception. Perception is transformed with every line and every glance, hence drawing is a process of perceptual learning. The distinction between drawing and other visually guided motor skills is that the hand is elucidating vision and perception while it draws.

In other skills the vision to motor / perception to action paradigm seems easier to apply.

For skills such as driving and playing cricket one uses the eye in the same way as in everyday vision; 'surveying' fixations capture information for the task, such as recognition of objects, of movement, and the tracking of movement. Vision informs subsequent action, for example, in driving vision informs the hand's motor action, to steer the car. Learning of the skill, and through on-going practice, feedback processes fine-tune the 'cause and effect' connection between eye and hand, to ensure that the goal is achieved.

However the goal is not reflexive in the way observational drawing is. In other words while drawing can be conceived as a perception to motor skill, like driving and sandwich making, it is distinct because the hand is trying to talk about, and augment, the looking. It is not solely using vision to direct action. There is an extra dimension wherein the hand is exploring perception itself, trying to under-stand vision.

In the case of observational drawing the hand tries to mirror the seen line. The hand isn't just trying to use the visual information towards a motor goal; rather it is trying to appreciate and understand it, to explore it, and to inform it. This exploration of the visual is what makes the hand a 'looking' agent, and gives an extraordinary connection between the visual and the motor. The contention of the thesis is that the eye and hand learn from one another, to the extent that the eye learns to draw lines and the hand begins to 'see'. To make this argument we need to be clear what is meant by seeing. I use the word to refer to perceptual processes that make sense of visual information. This is distinct from 'looking', which is a questioning and searching, an earlier stage of the visual processing system. In this way seeing is read as an interpretation i.e. what one makes of the visual information, an understanding, as implied by the use of 'I see' to mean 'I understand'. Whereas 'I look' refers to an earlier stage, to the asking of a question. Hence both the eye and hand contribute to 'seeing', to the understanding of visual information. Observational drawing is a way of seeing, that does not depend on the eye alone – in this way it is a multisensory perceptual process. We see by drawing, we use drawing to see/to understand. In everyday skills such as driving the work of the eye and hand are more distinct and separate, goal-driven without the metacognitive level of reflecting on and exploring perception. In this way observational drawing is an enactment of perception.

Rationale for focus on movement and the hand

This chapter asks whether the hand offers a more stable platform for perception. Along with the philosophical establishment of vision as the highest sense, computational modelling of bodily processes has strongly influenced the way we understand vision. Two contrasting paradigms of vision have led research since the 1960s, with Gibson taking a holistic view, and Marr (1982) approaching vision as a computational problem and a sequential hierarchical process. Computational models such as Marr's have inclined vision research towards a linear mechanical view, with corresponding methods of analysis. Computational and scientific methods often reduce complex systems to input-output models. Both experimental psychology and computer technology have influenced our conceptions of processes. While contemporary scientists have drawn attention to the action of the hand, they work within this familiar paradigm; the eye sees and the hand executes. In relation to drawing research this has led to the predominance of 'into the eye, out of the hand' informational models, ignoring the possibility of more complicated feedback processes, and designating the eye the role of perceiving and the hand the role of mechanical execution. Current scientific drawing research is also committed to this input-output paradigm, partly because of its efforts to locate drawing within a more developed field of cognitive science, the study of goal-oriented skills. However as outlined above drawing is unlike other skills, because the hand is not merely guided to act by the eye, but is trying to articulate the same thing as the eye, to reiterate and, furthermore, explicate the visual.

This chapter questions the eye-to-hand perception-to-action model of drawing, wherein drawing begins with the eye (visual sensation), progresses to perception (by the mind), and then to a visuomotor transformation that leads to drawing execution by the hand. My final model proposes that the eye and hand can perceive and draw the drawing together. This model finds support from artists' accounts of drawing. In science we have to look beyond drawing research into other areas of perception and action research to find those who entertain the idea that the hand contributes to visual perception in voluntary executive tasks (see Noë 2004, O'Regan 1992, Gallagher 2009). Artists' statements of how drawing feels and the transformation of perception arguably get closer to what is happening: free from the need to empirically test their assertions by splitting behaviour into conditions and variables, they are able to express phenomenological experiences that may closely relate to cognitive processes.

Structure of the chapter

The enactive drawing argument progresses from defining perception, to the role of perception in drawing, to a questioning of what drawing requires of vision - Is the eye up to the task? – to the proposition that the eye needs the hand in order to see in this especial detailed way. Proposals are made for how to bring the hand into the picture, feedback from hand to eye is explored, and the question of when the hand leads the eye is asked. Drawing is then posited as a dynamic conversation between eye and hand. Drawing is framed as presentation, rather than representation, leading to the proposition that drawing is a form of perception. The model of drawing is distinguished as a research rather than a depictive method.

Appendix 5(c) details the argument, using annotated drawings, from the dominant paradigms of the intelligent perceptive eye to an enactive embodied view of the eye and hand working together.

Section 5.3 proposes the model for testing in practice. It emphasises the need for a workable strategy, either explicit or implicit, relating to the coordination and use of the hand and eye.

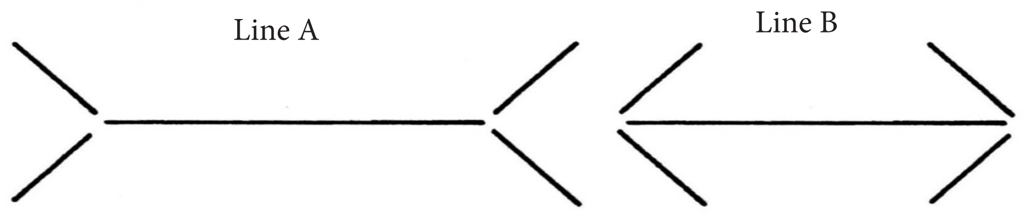


Fig 1.2 The Muller-Lyer Illusion - used to test perception of horizontal lengths of line A compared to line B

5.2 Establishing observational line drawing within enactive perception theory

At this point drawings and text explored in detail the process of observational line drawing. Please see appendix 5(c) for the drawings and supporting notes. The notes are only for reference, if required by the reader. The main argument is made in the drawings.

Drawing the Muller-Lyer figure

To explore how the action of drawing a line can affect perception, I asked Breuton to first look at the Muller-Lyer figure (figure 1.2), and to report her perception of the length of both lines. I then asked her to trace repeatedly over the lines. See figs. 1.2, 1.3 and interviews with author., Brueton 2014a, Brueton 2014b, and appendix 5(b).

After looking at the line Brueton said that Line A looked longer to her. (Brueton 2014a, 18mins)

She had seen the illusion before and knew that Line A is perceived by most people as longer.

I asked her to trace over both lines. (Brueton 2014a, 1min.14s):

After tracing over both lines twice, she said 'it's really interesting, cos they feel the same but my eye is still telling me that that one [points to Line B] is shorter, even though it feels the same as this [indicates Line A] .' (Brueton 2014a, 1min. 33s)

I then asked her to watch the pencil tip as she traced the lines.

After tracing over both the lines 14 times, she said 'I think they are getting closer, as in they still feel the same, but visually I think they are getting closer' (Brueton 2014a, 2mins 54s).

She said:

> My hand is making a similar action and I can feel through the tip of the pencil when the pencil is in contact with the paper, so that [she traced lineA], feels pretty much the same as that' [she traced line B] (Brueton 2014a, 3mins 33s.)
>
> I think I'm using touch and feel, and I'm using time, I'm trying to quantify time for myself, to try and convince my eye that that [she points to line B] is the same as that [points to line A].(Brueton 2014a, 8mins.:47s)
>
> ..but I did find that through drawing over them that the feeling of the lines were the same, and that began to influence how I saw them. I didn't, by the end of it, I didn't see them as the same distance – my eye was still telling me that that one was longer than that one, but the difference had reduced. (Brueton 2014b, 24s)

Onians believes that looking and attention cannot solve all perceptual problems. Talking of the Muller Lyer illusion Onians contends '

> If our neural networks have been fundamentally configured by some general feature of our experience no amount of intense looking at individual objects will correct the errors this leads to. (Onians 2007 p.90)

However, Brueton's experience suggests that in the case of the Muller Lyer illusion when we attend by drawing we can change our perception of the line. As Brueton noted, the fact that it takes the same amount of time to draw the line, suggests that they are the same length. Instead of relying on the eye alone, the hand helps to clarify perception.

Reader, please try this process of looking and then drawing.

During my interview with Lyons (Lyons 2013) I asked her to draw a clothes' peg. After drawing I asked Lyons whether the experience of drawing changed her in any way. She replied

> Yes, I do think but also I think with looking, I think I am drawing as I look anyway, because I am looking at it but I am thinking about how I draw it, I am looking at it in terms of how I am understanding it and how I would try and understand that and manifest that through drawing it, to get to see it and get to know it better. So I can't see behind it but I am thinking how that might look, and I am also thinking of it sensuously as in I am not going to touch it but I imagine how it feels' (Lyons 2013, 19mins 36s)

Drawing as presentation

Dr Lucy Lyons was one of the expert drawers studied by Tchalenko (2009a and Tchalenko et al 2014 in press). Her phenomenological study and analysis of the use of what she defines as 'delineation' (Lyons 2009) offers support for the argument that drawing can create a direct connection between the subject and drawer, made visible on paper, and containing a record and information about the engagement and interaction (Lyons 2013). In this way drawing sheds light on experience and our relationship with the world. It is a presentation of the bodily experience, not a representation of an isolated visual experience. This mode of drawing is important because it has great research potential, both in relation to perception, and across disciplines in terms of exploration and knowledge production.

The proposal of a motor connection between the eye and hand is consistent with the idea that an especially direct sensory link is made between the eye and hand. Drawing may be a more raw presentation of sensory information, with the perceptual process taking place on the paper, rather than in the brain before drawing. Perhaps drawing bypasses elements of perceptual processing, knowing that the drawing is going to do the thinking i.e. thinking occurs on the page.

Lyons defines drawing as a presentation rather than a re-presentation. This is an important point, conveying drawing not as 'after the event', but as the event itself. This positions drawing more clearly as a research method that presents a new view and contains new knowledge. Lyons used drawing (delineation) to research bone disease as well as to explore delineation itself. Due to this her focus was on the specific knowledge of the disease that delineation was able to discover rather than on the physics and character of delineation, as a drawing practice. I asked her, after she drew a clothes peg: 'Would you want the final drawing to really look like the peg?' She replied 'I would want the final drawing to not be a final drawing but to be the evidence, sort of er made visible, of my unique experience of how I'm seeing, and understanding, that peg to be' (Lyons 2013 18mins 57s). She continued '…and of it being about me getting to know the peg, so that if I drew that now it would not be the same as if I drew it tomorrow, or the next day or the next day, even if it was in the same place and at the same time of day.' (Lyons 2013 19mins 13s)

Lyons' way of drawing is a model of enactive drawing, where the drawing process is one of engagement with the object. To this end her eye locks on to the subject, focusing on the connection and discovery made through this. The principle behind this 'blind drawing' method is the maintenance of the connection with the object, and the resulting capacity to draw accurately. The connections between the three elements, the eye, the hand and the object are key. And these depend on orchestration of the whole body in the environment to provide the necessary conditions for drawing.

Drawing as perception

The thesis proposes that drawing is itself a perceptual experience. When conceived as a mode of exploration the distinctions between eye and hand begin to break down, firstly allowing us to recognize that both are motor agents, with the power to focus attention. Both the eye and hand engage in exploration. 'Situated cognition' recognizes that perception is entwined with action, even that it can be defined as a form of action. Drawing theorist McGuirk refers to descriptive drawing as a heightened mode of perception. (2011 p.9). This is my contention. We do not draw from perception, or draw our perceptions; we perceive. This is the theoretical foundation for the drawing method developed in Chapter 6, which explores and develops the premise that drawing is a form of perception.

Recently several practice-based researchers have argued that new knowledge is generated through drawing (see Cain 2010, McDonald 2010). McGuirk focuses on drawing as a knowledge producing activity, with particular reference to Noë's enactive view. He proposes that drawing is a form of knowledge, and then goes on to contend that perception is an inherent part of knowledge production. As he points out, knowledge production is, for obvious reasons, given a lot of attention in academia, and hence drawing research has often focused on the epistemological contribution of drawing practice, rather than on sensory and perceptual processes. When, as McGuirk does, we acknowledge that perception is an embodied way of thinking, research such as mine becomes relevant to contemporary concerns about knowledge production.

> In this view not only is perception active, it is in fact indistinguishable from the sensory-motor action of which it is composed and moreover (and this is a radical insight) it is indistinguishable from thought itself. This approach rehabilitates the claim of many embodied and situated making activities to be considered ways of thinking (McGuirk 2011 p.8)

Heidegger suggests that thinking itself is like building

> Perhaps thinking, too, is just something like building a cabinet...All the work of the hand is rooted in thinking. Therefore, thinking itself is man's simplest, and for that reason hardest, handiwork... (Heidegger 1971 p.381).

Observational drawing is both a means of building and of thinking. McGuirk also recognises the 'hypothesis testing' nature of both perception and observational drawing:

> …there is a correlation between what Noë understands as the dynamics of perception and the dynamics of descriptive drawing, because descriptive drawing demands the same kind of active searching, reaching, probing and testing that Noë recognises in ordinary looking.' (McGuirk 2011 p.8)

McGuirk suggests that drawing deserves an '…epistemological status as a heightened mode of perceptually based thinking…' (McGuirk 2011 p.8) while Noë states that 'perception and perceptual consciousness are types of thoughtful, knowledgeable activity.' (Noë 2004 p.3).

5.3 Proposition of enactive motor model of drawing, for testing by practice

The theoretical framework offers an alternative to 'withdrawing', distancing methods, such as measuring with a pencil or flattening the 3-d image using Alberti's drawing frame, by proposing a possible new relationship between the eye and the object (the external visible world) and the hand.

A new characterisation of eye hand interaction entails:

- Pausing and segmentation as keys to the skill
- Shared perceptual and motor roles for the eye and hand

- An enactive view of perception whereby perception occurs within action, rather than prior to action.

This new characterisation has the potential to inform drawing teaching, by integrating perception and action, proposing that movement and stillness of the body during drawing contribute to perceptual learning through drawing.

Interestingly, observational drawing imposes restrictions on movement and perception, because in order to maintain the same view one has to keep the body in the same position. Perception depends on movement of the body, therefore this stillness means that the eye and hand find particular ways of working in order to understand the visible. Noë writes that

> Perceivers have an implicit, practical understanding of the way movements produce changes in sensory stimulation. They also have an implicit practical understanding that they are coupled to the world in such a way that movements produce sensory change. (Noë 2004 p.66)

Noë draws to our attention the embodiment of perception within action, and particularly the importance of movement of the body for disambiguation of visual stimuli. This raises, for observational drawing, the crucial question of the impact of non-movement on perception. In drawing, movement is highly restricted, generally to the eye and hand. The practitioner keeps her head still. This means that particular visual ambiguities that would normally be resolved by movement, cannot be. The progress of the argument leads us to ask whether the stillness of drawing is the important factor making it an especial way of seeing, rather than the movements of the hand and eye. Noë points out that:

> Perceivers continuously move about and modify their relation to the environment. They do this is in order to get better vantage points and to bring themselves into contact with the relevant detail which is of interest. (Noë 2004 p.66).

His argument for the crucial role of movement in perception and perceptual learning led me to the insight that the particular conditions of observational perspectival drawing are extraordinary in that they restrict movement of the body, thus restricting access to normal ways of clarifying vision. The drawer enters an extraordinary world, where only head and hand movements are available as perceptual agents. In effect the drawer is disabled. This leads us to the possibility that sensory substitution may occur in drawers, in a way similar to that found by Bach-y-Rita in people who have lost access to one or more sense. For the drawer their implicit practical understanding is other than that of the general everyday perceiver. It is an understanding of the way eye and hand movements alone can change sensory stimulation and create useful meaningful percepts. As well as understanding that they are coupled to the world, they understand that the eye and hand are coupled in an extraordinary dance, alone confronting the task of making meaning of sensation in space and time.

The percept needs clarification. In effect the eye and hand have to do the work the whole body would normally do, for example finding ways to perceive depth, occlusion and distinguish between figure and ground without moving the body in space. Hence in answer to the research question 'what is the impact of observational drawing practice on perception?' I propose that by practising a 'fine-tuned detailed looking' and a stillness of the body we develop particular and unusual perceptual skills of the eye and hand. Furthermore the drawing practitioner learns about perceptual processes by this self-imposed physical restriction. She discovers how things look from a still point of view, how a very small movement of the head can distinguish an object from the ground, and learns to convey 3 dimensionality in 2 dimensions.

5.4 Discussion

An enactive characterisation of the drawing process challenges long-held views prioritising and isolating ocular vision, taking drawing into a haptic, temporal and spatial arena where we begin to discuss drawing's current and potential contribution for multisensory perceptual and cognitive learning.

Although drawing is recognised as a process of discovery, as well as of depiction, the theoretical underpinning of this is underdeveloped in terms of drawing's particular perceptual power, and how discoveries are made. Observational drawing slows the perceptual process down (drawing it out), enabling capture of detail, a focusing of attention, and a fine-tuning of the hand and eye. Like Tai Chi, observational drawing tunes the body, develops mindfulness of bodily and temporal processes and of perception.

Contemporary drawing practice is interested in gesture and the physicality of drawing, but it seems that this field of performative drawing distances itself from 'traditional' observational drawing, rather exploring connections between dance and drawing with the whole body, and fighting for an expanded definition wherein all bodily movement is considered to be drawing. Applying some of their insights and methods to more conventional forms of observational drawing may shed light on perceptual processes, and offer new ways of drawing. Paring back action to the eye and hand is a particular and focused way of engaging, perhaps akin to marking (an abbreviated form of dance practice) in dance rehearsal as explored extensively by cognitive scientist David Kirsh (see Kirsh 2011).

In the following chapter, I explore the temporal progression of observational drawing within the framework of navigational systems, i.e. I consider drawing as a form of navigation. Do drawers use some form of map, or do they feel their way by orienting themselves to markers in the environment? Observational drawing can use the external object or scene as the map, or progress detail by detail, orienting line with previous lines. The latter has more the feeling of discovering the wholeness of the object as you draw, rather than trying to represent the whole object, with a preconception of the whole. One draws the details, exploring how they will add up, and comparing it with the articulation of the external object. It is like completing a Sudoku puzzle, an deductive process building up from the parts, where if you take correct steps the solution will emerge, dependent on all the parts fitting together.

It is worth considering how different cognitive and practical approaches to drawing might relate, for example would a shift in approach facilitate a more direct connection between hand and eye? Where does drawing pedagogy stand within the new enactive view of perception? Do we need to rethink the perspective that drawing is 'all about looking'? Or can we redefine 'looking' to incorporate the perceptual contribution of the hand? In the same way that blind people see with their hands, do drawers develop, as Bridget Riley suggests, a special sight through their pencils?

When interpreted using Gregory's research model of vision, the eye can be understood to be repeatedly checking for errors, trying out visual hypothesis by suggesting paths of drawing to the hand, and checking whether they fit with a) the plan b) the appearance of the thing the line is aiming to represent. Is the imagined line a good match with the external observed line? Was it a good plan? Did the hand execute it well? This tallies with artists' accounts of the drawing process, as one of exploration and trial and error, and one in which the drawn line may inform the eye of possible perceptual errors. The important point to bear in mind is that everyday ocular vision is underdetermined, i.e. it does not offer enough information to support drawing. This is the line of argument that the thesis pursues, suggesting that the hand and eye mutually inform one another. It is this contribution by the hand that underpins the argument for changes in perception brought about by drawing practice – the hand manifests what the eye believes it sees – does the eye agree? If not the eye asks another question of the external object, and tries to find out more. The radical proposition from science is that if the plan is encoded as a visuomotor plan it is less vulnerable to the effects of visual illusion. Recent scientific evidence suggests this is the case (see *Think global, act local*. Fayena-Tawil et al. 2011) in which case it is very clever of humans to use elements of the motor system to limit errors the visual system may make. Gregory points this out, in the case of elucidation of vision by grasping, and as Beets et al. found, physically engaging with objects clarifies the percept.

The enactive view of perception holds that perception is a function of action, as distinct from the input output view, whereby perception precedes action. To this end we need to attend to temporal aspects of the execution of drawing, to gain insight into this action, and to explore feedback and iterative processes. If we accept that perception occurs in action, we can argue that drawing is itself a mode of perception, coordinating movements and stillness of the eye, the hand and body. Drawing does not simply use perception; the drawing itself is percept - a multi-sensory percept. The argument against this is that percepts only exist in the mind. Noë and O' Regan present a compelling argument that much of perception and thinking relies on external representations rather than mental representations. When possible we use the external world as working memory – this is like streaming a film rather than downloading it. We can watch it because it is there in the present. Therefore we do not need to create a mental representation of it. In observational drawing we can continually refer to the object for fresh information, drip-feeding the process.

The following chapter puts the enactive model into practice. The study developed a new way of teaching drawing that brings the hand back into the picture and attends to the physical bases of drawing, and considered how this can be taught. As a drawing practitioner and teacher I had questioned teaching methods, particularly the rationales offered in terms of perceptual and cognitive theory. For example Edwards' proposition of using the right brain, Ruskin's advocation of the innocent eye, and the central idea that one draws from memory even when drawing from life. To question these perceptual paradigms I developed teaching practices and drawing instructions which were underpinned by understanding of the theories and findings from scientific study, as discussed above: enactive vision theory of Noë and O'Regan, Gregory's model of vision as hypothesis testing, and Tchalenko's hypotheses about segmentation, 'blind' drawing and visuomotor encoding of information.

The model emphasises measuring by the eye, as touched on by Ruskin, and makes explicit the fact that the hand and eye mutually measure and analyse. This leads to the idea that they become more alike, learning from one another about movement, timing, space and touch. When we try to define the complex perceptual requirements for line drawing from life, rather than assert any notion of forgetting and innocence, I suggest that artists need to develop a new temporal way of engaging with the world and objects, specific to the task of drawing; more detailed and slowed down, drawn out. Enactive observational drawing is about growth and change, rather than capture. Ingold writes: 'In growth, the point becomes a line, but the line, far from being mounted upon the pre-prepared surface of the ground, contributes to its ever-evolving weave.' (Ingold 2010 p.6). In Ingold's words, drawing can unlock the world:

> Though we may occupy a world full of objects, to the occupant the contents of the world appear already locked into their final forms, closed in upon themselves. It is as though they had turned their backs on us. To inhabit the world, by contrast, is to join in the processes of formation. (Ingold 2010 pp.5-6)

Without an embodied framework, wherein the hand and body are acknowledged as thinking and perceptual, observational drawing does not have a leg to stand on within contemporary drawing theory, and cognitive science.

To summarise, an enactive framework for the study of drawing includes consideration of 'the legs' of drawing 1) how movements and stillness of drawing play out in time and space 2) the interaction between the drawer's body and the drawn object and 3) the interaction between eye and hand. I began by asking what would an enactive model of observational drawing look like. What are the conditions of observational drawing and what is enactive drawing? In other words, what drawing processes are implied by an enactive view. If, as according to the enactive view, action contains perceptual content, where can we find this in the movements of drawing? The debate about whether the key to drawing is 'looking' is resolved by showing that the hand contributes to visual perception, and is not merely a motor agent. By using drawing itself as a research tool, I explored the relationships between perception and action and the hand and eye using a combination of reflective and conceptual drawing practice. As a result I developed an enactive hypothesis relating to the conditions of observational drawing and the development of a 'special way of looking at things'. The hypothesis posits that accurate drawing hinges on rhythm, on interactions of the eye and hand, and on moments of stillness, precisely timed and placed. I put this hypothetical model into practice in my teaching instruction, outlined in Chapter 6. My conclusion is that looking involves the whole body. What makes 'looking for drawing' an extraordinary form of perception is the orchestration of eye, hand and body movements, and the conversation between eye, hand, mind and object.

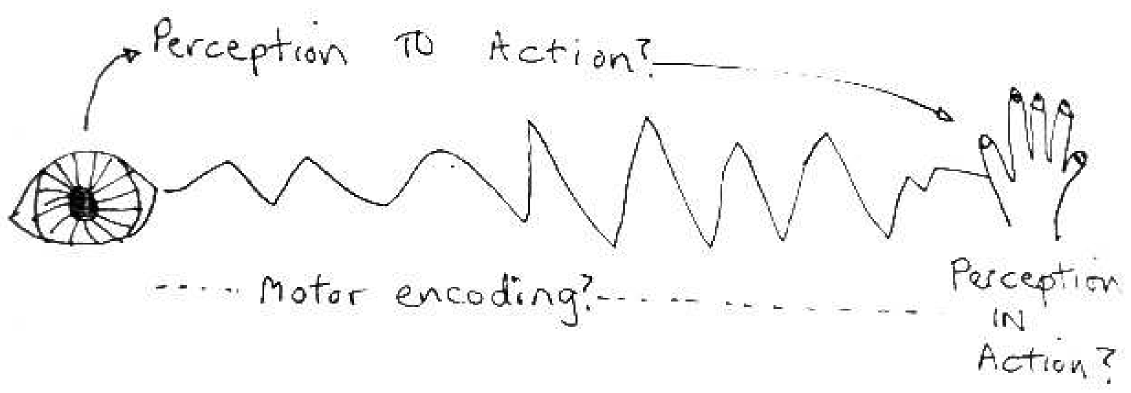


Fig. 6.1 String between eye and hand

Chapter 6 Development of a motor-based drawing method

6.1 Introduction

This chapter documents and illustrates the development of my drawing method, showing how it uses motor-based instructions for observational drawing, informed by recent findings from cognitive science and from this study. The research question sprang from my own drawing practice and its impact on my perception, as well as my Masters drawing research project, which explored motor learning in observational drawing and piano playing. My first step in this practical phase of research was to translate scientific findings from the Drawing and Cognition Project (DCP) into drawing instructions. By framing observational drawing as a matter of movement and interaction my practice explored the role of the hand, the communication channel between the eye and hand, and the relationship between perception and action. I specifically explored how Tchalenko and Miall's scientific findings about motor encoding, eye hand interaction and segmentation of the image might inform teaching practice. This scrutinised the scientific findings in practice, asking how fully they model the observational drawing process, and how effective they are for teaching. I developed a drawing method based on instructions to segment the image, to draw slowly and to adopt a specific pattern of eye and hand movements. Crucially, I found that I needed to add feedback and assessment elements to the model to make it effective. The new method offers an alternative, arguably easier, way to learn to draw, without the need for analytical measuring techniques and calculations. By shifting the focus from cognitive to physical behaviour the method relies on an awareness of and attention to movement and coordination, thus radically diverging from existing approaches to observational drawing. The instruction aims to utilise our proprioceptive skills to synchronize eye and hand movement, and to explicitly focus on segmenting the drawing process, both into small segments of line and short episodes of time drawing. With added feedback and assessment elements, and instructions to snychronise the eye and hand suggested by my own practice, the method worked both as a new way to draw and to teach.

While working in DCP and conducting my study of Edwards' students I began to conceptualise the eye hand connection as a piece of string. See fig. 6.1.

I asked how we could shorten the string and make the journey as direct as possible. I hypothesised that a shorter route for the information, with as little change as possible would lessen the chance of distortion of the line and offer a good method for drawing. This led me to explore the idea that the eye and hand could try to behave like one another, under the rationale that this could potentially minimise the translation needed between sense and action. As psychological research has found, observational drawers possess extra-ordinary perceptual skills, ranging from fine motor control of the eye and visual discrimination skills. At the heart of the thesis is the proposition that the eye learns to move more like the hand, and the hand learns to perceive by 'touch at a distance', hence to contribute to vision.

The method rests on the proposition that timing matters for observational drawing. Synchronisation of movement coordinates the body, and informs vision and perception. Drawing is an especial example of the human capacity for moving, learning and imagining, and hence our agency, our power to transform the way we see things, and how we relate to them.

The theoretical perspective of Merleau-Ponty (1908-1961) was informed by his critical knowledge of the emerging science of cognition. My approach through practice was to try to enact, to physically articulate, theory from divergent fields, hinging on the idea that the body, in this case especially the hand, contributes to thought and vision. As documented in Chapter 2, the views of Ruskin, Merleau-Ponty, Edwards, Nicolaides, Bridget Riley, Tchalenko, Gregory and Noë present a range of perspectives on the role of the eye, the hand and 'drawing perception'. When Bridget Riley talks of coming to trust the eye at the end of her pencil (2009 p.20) she points to the role of practice and the contribution of the hand to visual perception. My emerging drawing practice is informed by Ruskin's idea that the sharp pencil sharpens the mind, by the view that action contains perception, and by Tchalenko and my own findings about coordination of the body and its implications for cognitive processes.

I conclude with the proposition that the drawer both a) learns, and works within, the limits of their perception, and b) extends these limits by developing their perception. Learning one's limitations demonstrates a knowledge, probably often implicit, a know-how, of how much information can be translated in one moment. Experts draw short simple segments of line in one go, with frequent glances to the original, and pauses between segments. Through practice perception develops and the conversation between eye and hand, and world and person deepens.

As outlined in Chapter 5 central to the argument is an enactive account of vision. From this view the role of the hand and the body are always significant in the perceptual equation. Only by considering the dance of eye, hand, head and body can a complete picture begin to emerge of the drawing process, of perceptual style and transformations.

Subjects of study

My drawing and teaching practices explored the use and teaching of:

1) Motor planning

2) Segmentation

3) Pausing

4) Hand-alone / blind drawing

In pedagogy the emphasis has been placed on looking. Students notice changes in their perception, and often state that they are 'seeing things differently'. The hand plays a crucial, though underplayed, role in this transformation of vision. My drawing instruction articulates the strong connection between the eye and hand, informing students of recent scientific findings and how these may contribute to drawing production. Behind the instruction is the proposal that informing students of the patterns of synchronisation of eye and hand of experts, i.e. Tchalenko's model of expert drawing behaviour, will assist the drawing process.

Methodology

Learning to draw accurately is hard to quantify and analyse through experimental studies, as peoples' level of motivation vary, and this is always going to play a large part in their ability and speed of learning a skill. My exploration began with the question 'Does the hand need the eye'? And if so in which situations, i.e. when does the hand need the eye? This then poses questions about why the hand may need the eye and whether the drawer knows this explicitly or implicitly. The drawing instruction was initially developed from scientific findings, but then moved into speculative territory based on experience and questioning of how the eye and hand operate, particularly 'in between' sensation and action. The opportunity to practically explore and go beyond science results in questions that I hope will be taken up by scientific researchers, to clarify where, if at all, we draw the line between perception and action, and how perception operates in observational drawing. To some degree this has begun during my research, with psychologist Chamberlain testing ideas we discussed about motor memory, Tchalenko and Miall's findings and the question of whether drawing experts brains change structurally (see Chamberlain 2013).

Like Ruskin, I explored 'elements of drawing' through participation in both the learning and teaching processes, through engagement and reflection. Insights were related to quantitative findings, and were used to inform the research path, generating new avenues and approaches for study. In addition the exploration was guided and mediated by my engagement with scientific practice and findings. In this chapter drawings are linked to reflective accounts of my experience and to current scientific theories and findings. Excerpts from drawing diaries outline how insights from my own studio practice influenced the direction of my quantitative studies. Excerpts from student's accounts and diaries reflect on their own drawing practice and experience of my teaching. These often echo published accounts, with the frequent observation being along the lines of 'now I see things anew'.

6.2 My drawing instruction

See accompanying DVD for recordings and demonstrations of my enactive drawing method.

Enacting vision

The key point to emphasise is that drawing scrutinises vision, and transforms it, rather than draws from it. Drawing is an extra-ordinary multi-sensory way of looking, wherein the hand does not immediately accept the quickly captured information by the eye (the 'first glance'). The hand questions it, and asks for more detail. The eye is not adequate to the task, so the hand gets involved, by collecting information itself, and also by teaching the eye how to collect detailed information.

The instructions presented here hinge on the idea that during drawing there may be phases when the movement of the eye synchronises temporally and spatially with the hand, with the eye staying fixated on the original and the hand drawing on the paper, rather than drawing from visual memory. This is an extension of the visuomotor hypothesis of Tchalenko and Miall as outlined in Chapter 2. The idea is that proprioception can play a part, as well as visuomotor encoding, when we take into account the integrity of the body. Proprioception refers to one's sense of one's own body and how movements of the parts of the body relate. It is an inner sense of articulation, coordination and balance. In order to follow the line the eye obviously needs to see it, but rather than concentrate on the visual capture of information the eye slowly moves along the line, as if drawing it. In scientific terms the eye may simply be fixating more often and hence capturing more frequent and more detailed information. Experientially it feels like the eye is drawing the line, and the hand is mirroring this. The hand is enacting and participating in vision, in this case by mirroring the movement of the eye. The first step of the instruction in fact asks students to draw along the line with the pencil itself, which I have termed 'air drawing'. In this way the eye and hand together are questioning, answering, checking and reinforcing their mutual ideas about what they are looking at. They are working on the same project.

Focus on eye and hand movements

The common view is that the eye perceives, and the hand follows. The premise is that if you learn to look then you can draw, implying that the mechanical act of the hand will follow easily. To a large extent experimental research of drawing has operated on this paradigm, adopting a sequential model with the eye looking and perceiving, and the action of the hand following information from the eye. My perspective, from my own teaching experience and observational research, is that students often struggle to integrate and coordinate their eyes and hands, and that being more explicit about how the hand and eye synchronize will facilitate learning. The first point to bear in mind is that the eye moves a great deal during observational drawing, making many fixations and weaving a web of connections. Physiology of vision tells us that smooth movement of the eyes is only possible when following a moving object. From my practice and feedback from students this seems to be the case experientially as well as experimentally. When I ask students to move their eyes slowly and smoothly they find it difficult and challenging. Students are aware of the jerky movements of the eye and are unable to counter the jerks. I tried pursuing an imaginary ant with my eye, but still found that my eye never feels as if it is moving smoothly. This is of interest in relation to drawing moving objects, for example, the interrogation of movement with drawing. In this case the eye certainly can draw the line, in what is termed in vision science 'smooth pursuit', following a moving object. In Jen Wright's research practice (in Kantrowitz, Brew and Fava 2011 pp.109-113) she mirrors the movements of surgery. Due to the ability of the eye to move smoothly when watching and following action (see Land and Tatler 2009 p.23) this is a very different process from conventional observational drawing. In terms of drawing as a research tool this is an important point, as using drawing as a mirroring tool for movement holds much potential. However due to the physiological difference in eye movements it is not at all the same process as observational drawing of a still object or scene. My observational drawing method was informed by this 'tracking' mode of drawing, trying to move the eye as smoothly as possible despite not having a moving object to follow.

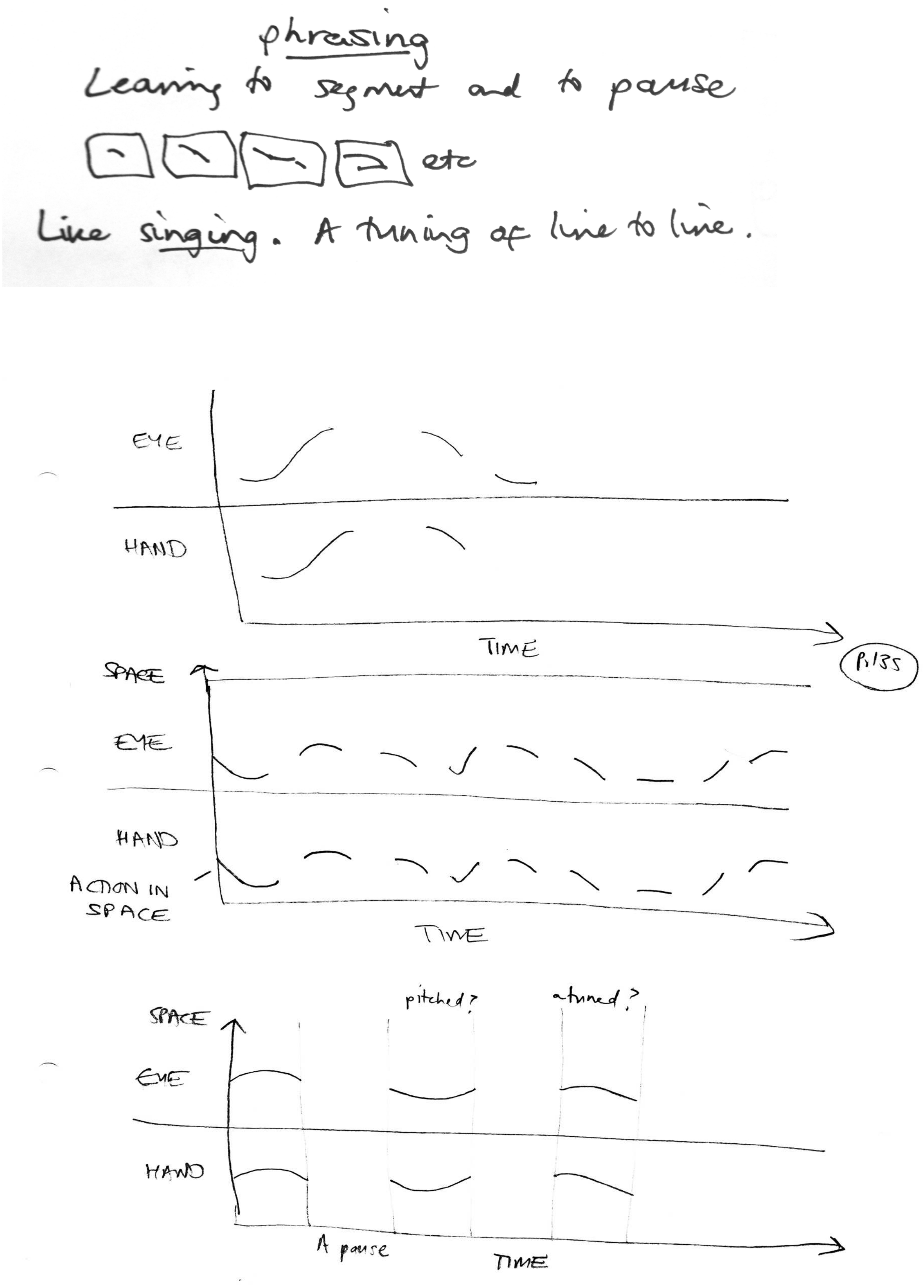


Fig. 6.2 Pitch of drawing - eye and hand synchronisation in time and space

As we saw in Chapter 2, Nicolaïdes urged students to look for the energy and gesture in still lives. Drawing lines potentially aids understanding of processes of growth and evolution, forging an understanding that goes beyond 2-dimensional imagery, relating to underlying principles of nature and physics. This point, as distinct from learning how to draw from nature, was made by both Ruskin and Nicolaïdes as a reason to draw (Nicolaïdes 2008 p.2). Another possibility is that drawers may potentially 'see' their own plan for drawing the line, i.e. foresee their drawing action, which is an affordance of the object. This would entail a conception of the line that they plan to draw, in terms of imagining an action, rather than creating a mental image to draw from. Nicolaïdes does not refer to this, but it is suggested by Tchalenko's findings about motor planning and the recent discovery of mirror neurons, that are activated when imagining action (see Gallese 1999).

At the start of my research in DCP Tchalenko was beginning to explore the role of visuomotor planning and encoding. As explained in Chapter 2 Tchalenko and Miall suggest that drawing from life relies on the encoding of visual information into motor plans. In other words the drawer converts what they see into a plan of how to draw it. This finding forms the basis of my instruction. It focuses attention on timing and the role of physical practice in the perceptual learning required for drawing and understands that transformations of perception come about through movement and knowledge of movement, through physical engagement with the external world. As Noë emphasises, and as outlined in Chapter 5, perceiving is a way of acting, '…not something that happens to us, or in us. It is something we do.' (Noë 2004 p.1).

I thought about skills that are easy to acquire and come naturally to most people, due to the integrity of the human body. To this end my first set of instructions focus on the unity of the body, proprioception and our ability to synchronize movement. The eye can communicate with the hand without using any form of visual memory. Rather, the hand moves along the line at the same time and at the same speed as the hand, creating a physical motor translation rather than a perception-to-action translation. This is synchronised both in time and space. Tchalenko and Miall found that for the hand to achieve accuracy in drawing the shape of simple lines, the eye does not need to look at the hand as it draws or to check the drawing as it emerges. However, from results of copying tasks in which participants did not look at the paper, or their emerging drawing, they concluded that the hand does need the eye in order to piece together the segments of lines accurately in space on the paper.

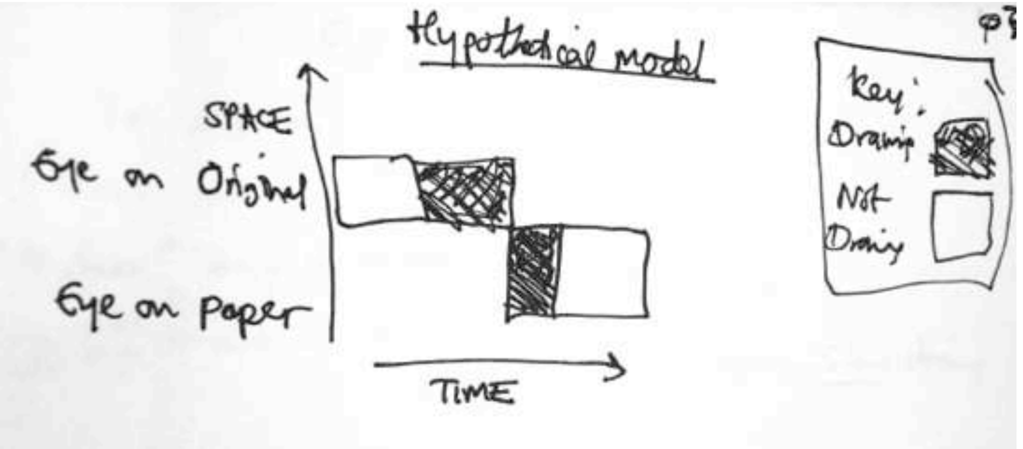


Fig 6.3 Simple phrasing of drawing. NDo Do Dp NDp

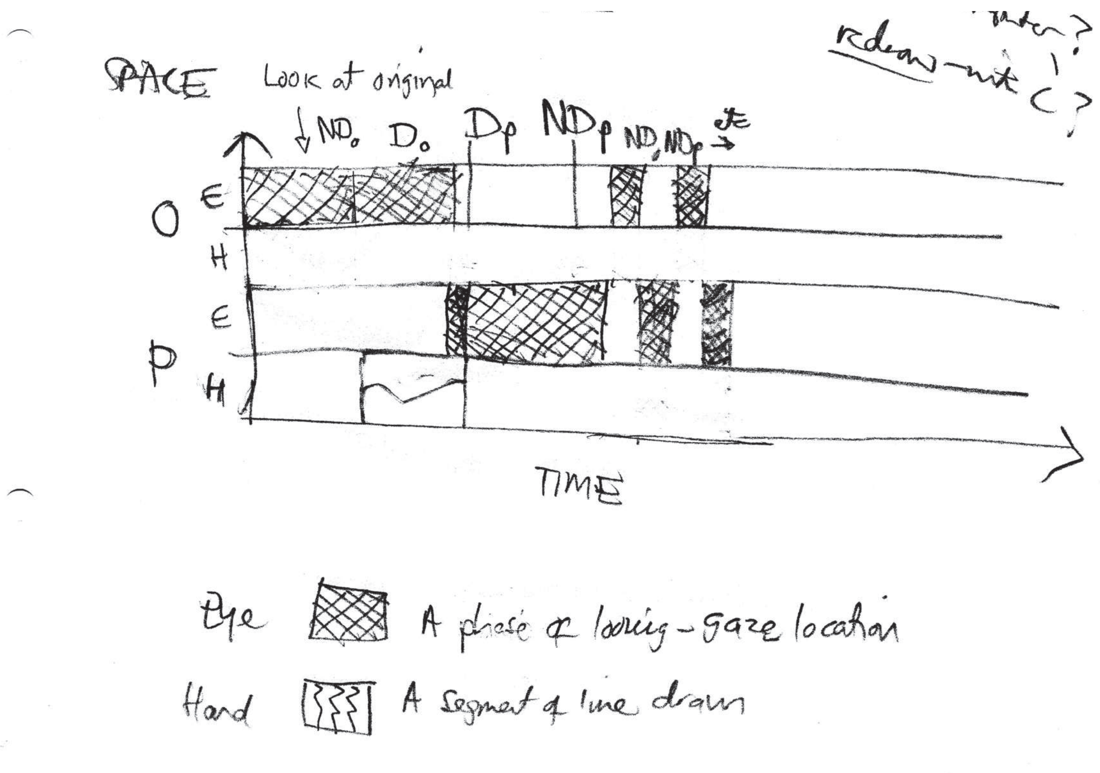


Fig.6.4 Drawing phrase with assessment. NDo Do Dp NDp NDo nDp NDo NDp

Phrasing - learning to segment and pause

This translation, from line to line, is like singing; in observational drawing the practitioner is trying to echo the line, in the way a singer, who is sight-reading or listening to another voice or instrument, pitches the voice to sing a particular note. See fig. 6.2. Both the singer and the drawer are tuning, using a matching process, which relies on sensory feedback and reflection. Moreover drawing, like singing, phrases the segments and uses the equivalent of breaths between these, in the form of pauses. Relating the learning of observational drawing to both dance and singing highlights important aspects of bodily control, skill and expression. Crucially observational drawing, dancing and singing all commonly entail the ability to imitate and to plan a matching action. They translate an external object or event into something they do themselves, to correspond; a movement, that might be a visible gesture or a sound. In this way all are forms of enactment, through their reflexive nature.

Tchalenko's results relating to 'drawing blind' (with eyes on the original) raised interesting questions about when this may be an appropriate hand-eye strategy, when used in conjunction with a strategy to monitor the evolving drawing on the paper. The ability to draw 'blind' implies that an efficient approach, making good use of perceptual resources, is for drawers to keep their eye on the original while drawing, only glancing at the paper as the pencil is completing the line.

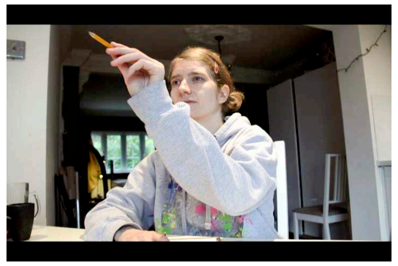
See fig. 6.3. My hypothetical model, based on Tchalenko's findings, for copying a single complex line became:

Step 1. Participant looks at the original (NDo)

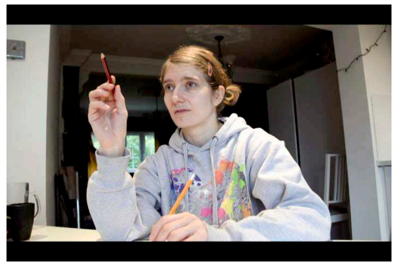
Step 2. Some drawing is executed 'blind' / hand-alone, while looking at the original (Do)

Step 3. Drawing continues while looking at the paper, to control the spatial position of the line (Dp)

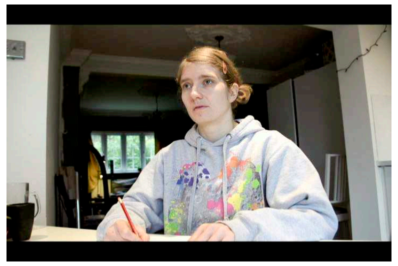
I added a fourth step: Not drawing while looking at the paper (NDp), to allow time to assess the line before comparing with the original, and starting another cycle of drawing action. Between cycles of NDo Do Dp NDp, glances back and forth between original and paper may be used to compare the original and paper. See fig. 6.4.



Air drawing



Air drawing



Synchronising eye with hand

Blind drawing

Blind drawing

Fig. 6.5 Brueton (CB) filmed during a drawing lesson by the author.

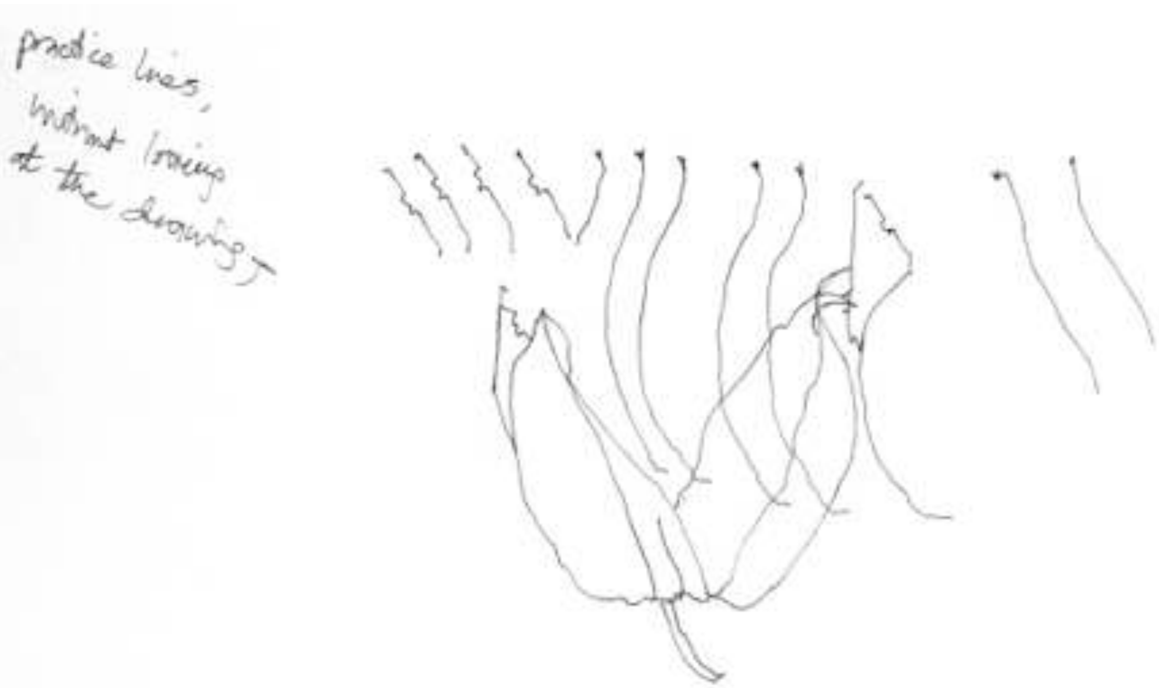


Fig. 6.6 Drawing blind; warm up exercise. An example from author's practice of lines drawn with out looking at the paper, to connect eye and hand and encode lines to motor memory

Outline of the drawing instruction

See appendix 6(d) for audio of a teaching session, 2013. See fig 6.5.

The method

In drawing classes I begin with some eye movement exercises.

Phase 1 Eye exercises

1) I ask students to follow my pencil tip with their eyes as I draw a line.

2) I then ask them to trace the drawn line with their eyes.

3) We then discuss the differences they found in the two ways of moving their eyes.

4) I explain the difference between smooth pursuit when tracking the moving pencil, and the characteristic saccade and fixation movements of tracing a static drawn line.

5) I explain that my instruction is based on training the eye to move slowly, see detail and to draw lines in space.

6) Then I ask students to imagine an ant crawling down the line and follow it.

7) I ask them to practice drawing slow lines with their eyes. I introduce the term 'eye drawing' to refer to this practice.

We then move on to exercises to synchronise the eye and hand.

Phase 2 Synchronising eye and hand

1) I ask students to practise drawing simple segments of lines in the air with the hand as well as the eye. This entails tracing of lines perceived in the external world (e.g. in a face, a vase, a landscape) with the pencil. I call this 'air drawing', defined as drawing in the air by the hand, tracing a line on the original to be drawn.

2) I instruct students to use both hands to draw the line in the air and on the paper at the same time. This creates a correspondence between the external line and the line on the paper. (I suggest that they draw the line in the air with their non-drawing hand, and the line on the paper with the hand they normally use to draw or write, but some students prefer to do it the opposite way. Either is fine.)

3) I then ask students to synchronise the eye and hand, to 'eye draw' with the eye, while drawing on the paper with the hand. I instruct them to move the eye and hand at the same speed, drawing two lines that correspond on a one to one scale, one in the air and one on the paper. See figs. 6.6, 6.7 and 6.11.

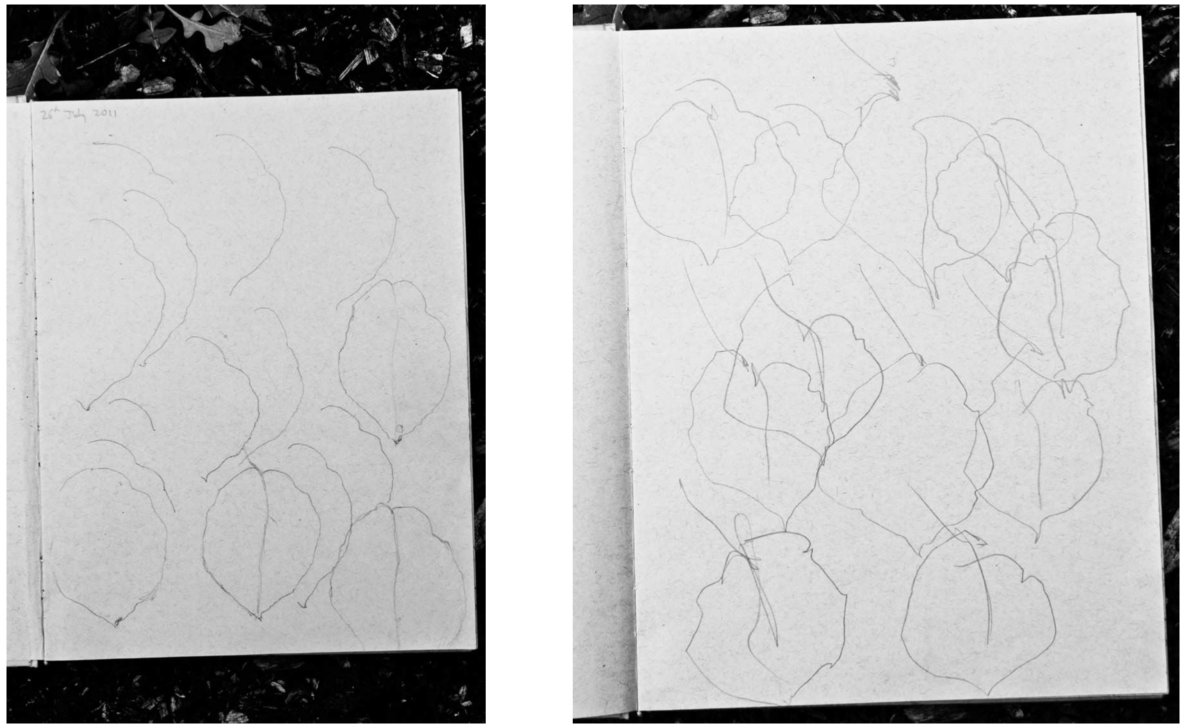


Fig. 6.7 Warm up lines, segments drawn blind. 26th July 2011, Drawing Growth Project, Pear Tree Series Diary 2.

Phase 3 Segmentation

1) At this point I explain Tchalenko's findings relating to the novice ability to copy simple line segments.

2) I instruct them to draw a series of short line segments keeping their eye on the object and without looking at the paper.

3) I then talk about segmentation. I explain that the Drawing and Cognition Project found that novices are as good as experts at drawing simple line segments 'blind' without looking at the paper. This is an important point as it reassures students that they can draw. When they look at their paper after drawing a series of segments they see that the lines are similar, and they realise that they are succeeding in translating a simple segment of line from the external world into an equivalent line on paper.

4) I propose that drawing can be learnt primarily by forging this strong connection between the eye and the hand, by a direct connection between the line the eye perceives and the line the hand draws.

5) I also propose that blind drawing establishes a strong connection between the drawer and the external world.

6) I suggest that this reframes our view of observational drawing as moving closer to the world rather than a withdrawal, which can be viewed as a disengagement.

Phase 4 Joining segments together

With the mode of drawing simple lines established, I introduce a way to join the segments together.

1) I tell them that joining the lines together is the distinguishing skill that experts have.

2) I instruct them to look to the paper just as they are completing the drawing of each segment of line, to monitor the completion and end point of the line.

3) I instruct them to pause once the line is drawn, and to use their eyes to compare the segment with the corresponding line on the original.

4) I go on to suggest that they also use their hand to compare length and angle of line, as this gives an additional check in the form of the student's perception of how long it takes to draw the line, and a proprioceptive sense of the angle of the line.

5) I instruct students to correct angle and length of lines, either by erasing or some other form of crossing out or labeling lines as incorrect.

6) I explain that the method depends on allowing errors to be made in the form of provisional

and contingent lines, and on using a pencil and eraser or other correction tool or method.

7) I instruct students to continue to pause to give them time to choose a starting point for the next segment.

Phase 5 Rhythm – Drawing in time and space

1) I then teach students the characteristic rhythm between eye and hand, original and paper, with glances to the paper at three moments and for three purposes: at the start and end of a segment, and during pauses between segments to assess the lines.

2) I instruct students to launch lines from starting points, but not to worry about the end points.

3) I explain that end points will become clear when other lines are drawn, in the same way as creating geometric shapes end points are clarified by where lines intersect (triangulation). This is particularly clear in drawings of plants, where a mass of crossing branches and leaves can be built up in relation to one another.

4) I explain that this method, proceeding detail by detail, exposes errors in angle of lines as the drawing emerges.

In detail this entails: Choose a start point A. Draw a line from this point, at an angle that corresponds with the line in the original. End it once you have drawn a short line, at a point of your choice, either when the angle changes, when you feel your eye and hand have lost their connection and are out of sync, or when you feel like it. Pause. Compare your drawn line to the line in the original. Correct if felt necessary. Look at the original. Choose the next line. Choose a start point for it. This should be either point A or near to point A. Launch line B. Repeat process as per line A. Draw a third line C. At some moment the lines drawn will intersect. At this time the point where, for example, line C meets line B will serve as a check for accuracy of lines drawn. It is like a puzzle – if all lines are drawn accurately in terms of the two parameters of start point and trajectory the lines will intersect correctly – i.e. corresponding with the line intersections in the original. Amend the lines as required to intersect at correct points. And so on. In this way lines become anchored with other lines and the drawing becomes anchored on page. Finally it all joins up, and the drawing problem is solved.

Through this focus and effort students learn something about the object and how its part make a whole, for example, how a branch grows, the proportions of a jug and how it sits on the table.

Notes on the method

Thus drawing skill is built up in steps. In chronological order the background and rationale to each step of my drawing lesson is as follows:

Phase 1: Steps 1 and 2 demonstrate in practice the physiology of the eye, to develop awareness of characteristics of saccadic and ballistic eye movements, and the distinction between smooth pursuit of a moving target and looking at a still image. Step 2 highlights that the eye is designed for quick capture of information, and recognition from a glance rather than moving smoothly over objects, capturing sensory information bit by bit over time.

Steps 3-4 explain the scientific context of this.

The following steps 5-7 in this phase introduce and put into practice my ideas about eye and hand movements, how the eye and hand begin to learn from one another. This introduces an awareness of movement, and a step towards training the eye to move more slowly. Interestingly some students have said that imagining an ant crawling along the line helps them to move their eyes more smoothly.

Phase 2 continues practise of synchronising the eye and hand. While Nicolaïdes suggests that students should imagine touching the object with the pencil, in this case the 'air drawing' gesture is a preparation for drawing, an encoding of the line into a motor plan for the hand, i.e. practising the line. They do this several times and then draw the line on their paper, to see whether they have a muscle memory of the line, and can draw it on the paper.

Step 2 moves towards syncing the eye and hand, by syncing first the left with the right hand. The point of this is to show how we can use awareness of the body to coordinate movement. In step 3, the first time the eye and hand interact, the eye moves slowly along the line in time with the hand. At this stage the eye never looks at the paper. This serves two purposes; to keep the eye on the object, and also to prevent the student from judging their drawing, which can disrupt the process. This establishes a style of active slow close-looking, locking the eye on to the object. Both the eye and hand are used as drawing tools. Repetition of the same line, drawn by both eye and hand, establishes a particular eye hand connection.

Phase 3 concentrates on learning the segmentation process, and explains scientific findings of novice abilities. As outlined, this builds confidence and establishes the foundations of drawing. All they need to learn after this is how to join up segments.

Phase 4 and 5 teach this. The assessment of accuracy is an interesting defining element of drawing execution, as many other skills rely on a less equivalent outcome to assess their success, e.g. batting at cricket, where the eye hand coordination is translated into a new action, with nothing in the external world to compare it with. I explain the opportunity to assess the drawing, to compare the line produced with the original.

Step 2 in phase 5 teaches students my method whereby lines are launched, but not ended.

In the same way that the drawing is launched, without an idea of the end, apart from a commitment to accuracy of detail and a provisional visual hypothesis of what the finished drawing may look like. The drawing is going to follow the lines, and see where it ends up. To achieve this the eye and hand are going to follow the lines. In a literal sense the process is one of imagination – creating an image. It is a process of imagination, not reproduction.

The method relies on an on-going contact between eye and object, an openness to discovery rather than a capturing and chunking of information.

Reflections on pedagogy

As outlined above, starting with drawing simple segments and telling students that this is not an expert skill but rather something novices do just as well, builds confidence in ability to draw. The segments drawn on the paper provide students with visual evidence that they can reproduce simple line segments using proprioceptive ability. Furthermore it introduces the possibility of using the drawn lines as external evidence of performance – the student can assess the accuracy by direct comparison with the original, with no need for recourse to memory. The premise is that the eye behaves like the hand, offering a direct translation of movement. The hand moves at the same speed as the eye, drawing equivalent lines superimposed on the object-being-drawn and on the drawing. This establishes a way to draw an accurate line from life and encourages students to draw only short segments of line. This smooth slow way of moving the eye is easily learnt, in contrast to some drawing instructions relying on using an external measuring device e.g. measuring with a pencil, which require mental calculations and a less direct way to map from vision to hand movement. The instruction hinges on our proprioceptive awareness, rather than attending to looking alone. We start to learn to draw by attending to our whole body and how it engages with the object. In response to the initial instruction to draw a simple line students usually drew more complex segments than suggested, but it emerged that they could draw even these fairly accurately, and it became a good starting point for teaching; they understood that they, even as novices, can draw segments of line accurately. This was a surprise to students, especially as they were convinced that it would be impossible to draw accurately without looking at the paper. This

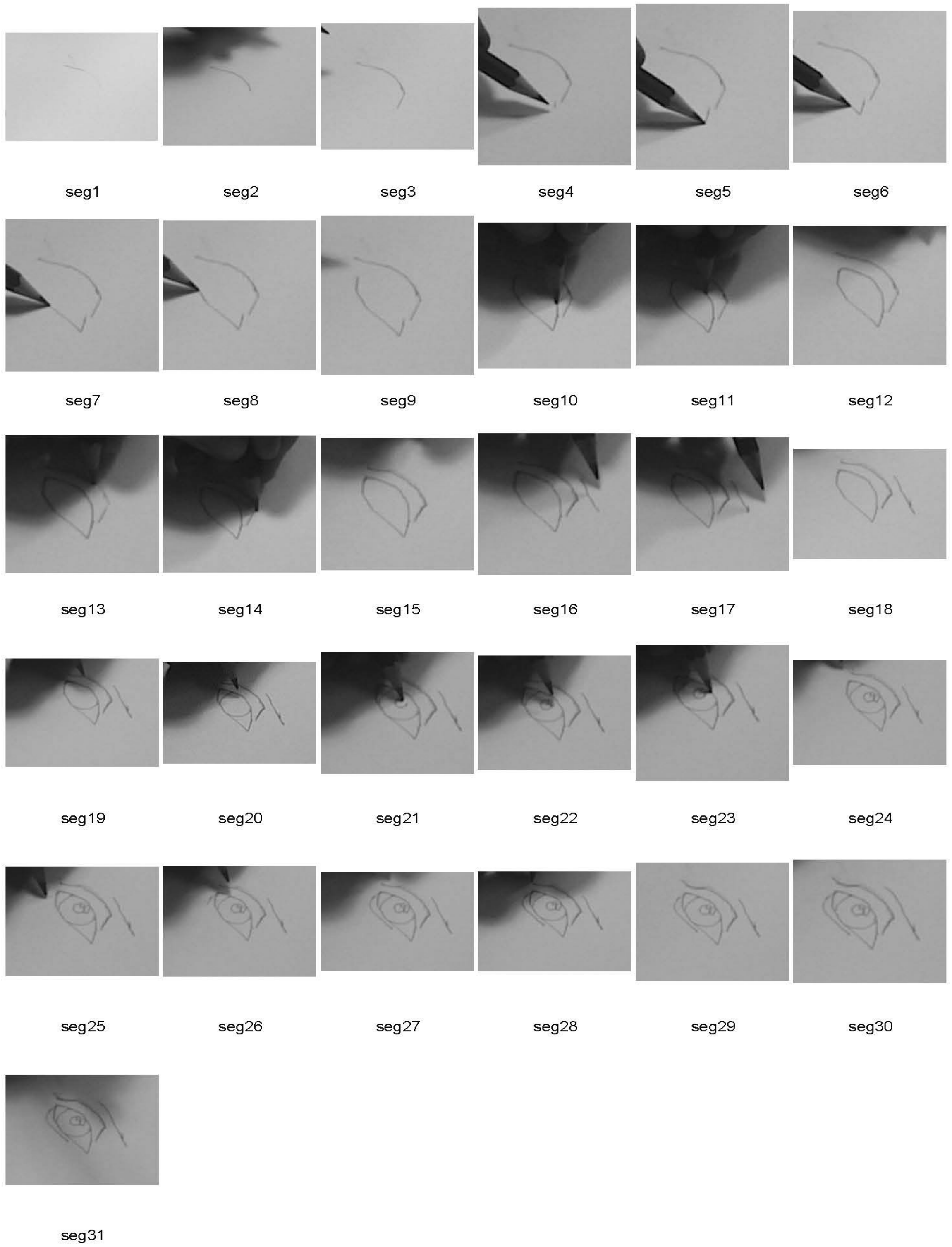


Fig.6.8 Segmentation process. Stiils from video clip Self portrait October 2013. See appendix 6(b), 6(c).

Fig. 6.9 Four line segments, drawn over 16 ½ seconds. See appendix 6(c).

shifts the focus from the drawing to the world, and also from the noun 'drawing' to the verb 'drawing'.

The instruction that students glance to the paper as they are about to complete the line segment fits with Tchalenko's findings in terms of behaviour and the monitoring of where the line 'lands'. However it is important to note as well that in natural settings the function of looking at the paper usually serves a more extensive, and pivotal, role: that of assessment and feedback. A central difference of my method from conventional pedagogy is the attention to temporal aspects, to the timing of hand and eye. My research explored what can be achieved by attending to movement and by utilising new knowledge from science of how experts move when they draw. Being able to inform students of scientific findings about the relationship between accuracy and the need to look at the paper, and the precise timing of this is an interesting contribution to observational drawing pedagogy. The important insight is to understand that observational drawing is as much a physical embodied process as is contemporary performative drawing. The distinction is that it explicitly enacts vision through observation of an external object, while performative drawing often visualises the movement of the drawer or another, offering a trace to aid understanding of their own being and active engagement in space.

6.3 The enactive method in practice

Segmentation

Fig. 6.8 contains stills from video of drawing a self portrait, a sequence of the first 31 lines drawn in a self-portrait. Segments are divided by pauses of at least ¼ second, usually longer, some with the pencil remaining on the line and others with the pencil lifted off the line. This shows how my drawing process uses small simple segments of lines.

The video clips in appendices 6(b) & 6(c) show the slowness of my drawing. The sequence of four line segments drawing the bottom eye lid took 16 ½ seconds. See fig 6.9.

The next figure, fig. 6.10, shows the self portrait drawing further 'down the line', to give an idea of how it progressed.

Fig. 6.12 shows drawings of a leaf, made during an eye tracking session at Loughborough University, July 2013, included to show the capture of detail possible using my method.

My interview with Lyons (Lyons 2013) confirmed much that she wrote in her doctoral thesis

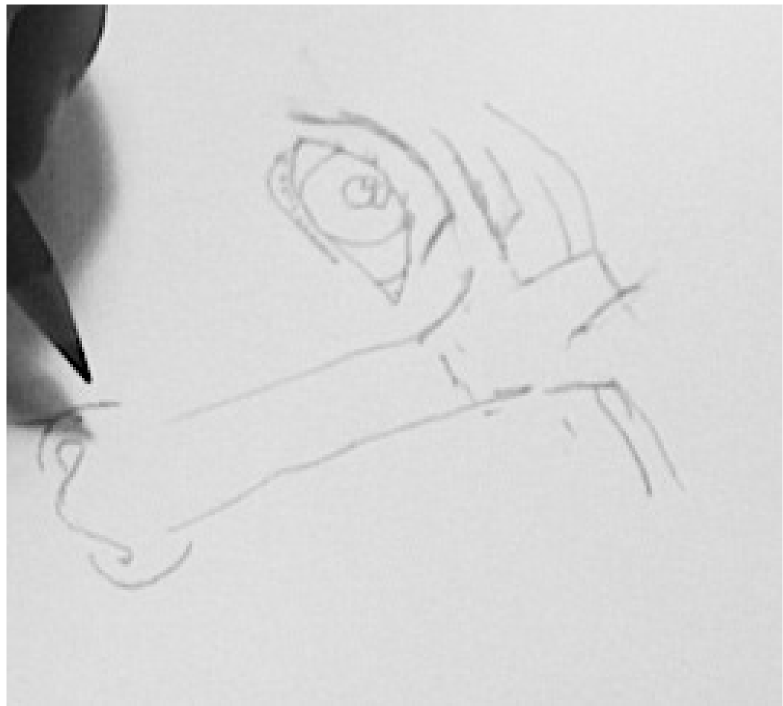


Fig. 6.10 Self portrait in progress. By author, October 2013

Fig. 6.11 Warm up blind line segments. Self portrait, October 2013

(2009), emphasising that for her drawing proceeds locally, part by part. We identified that her approach is very similar to mine, and that we consider our method of observational drawing to be performative, enactive, embodied and for discovery. Interestingly she said that for her the pause serves as a place to breathe and to re-anchor herself to the looking rather than slipping into drawing from what she knows about a thing (Lyons 2013, 21mins 49s, 24mins 4s). We both identified our practice as between observational and generative drawing, in that we have a part to whole approach, without a preconceived end product in mind. The method is useful across disciplines for education, as a research and explorative tool rather than for illustration or representation. She also emphasised the temporal nature of her drawing, with the output being a record of time and action of her drawing and her engagement with the object, rather than a picture or record of the object. She stated emphatically that when drawing the length of the line that she did it by an awareness of the pencil travelling a distance, not by an awareness of a start and end point. This was the final point she made. See fig 6.13 peg drawing and video interview, Lyons (2013).

Smooth drawing / blind drawing

Fig.6.14 is a still from a video clip with eye tracking data superimposed, to show my gaze path while copying a line. The pink line shows the path of my eye as I drew the line displayed. We can see that my eye was at a corresponding point on the original in relation to my hand.
In contrast, fig. 6.15 shows a more conventional method of observational drawing, with the gaze switching back and forth between original and paper.

Drawing growth

Fig. 6.16 shows images of a pear tree branch that I drew over a period from 2011-2013. I drew the same branch in 2011 and 2013 with a break in 2012 season where I was working on other tracking projects. The DVD contains the whole series in chronological order. The aim was to use my drawing method as a way to observe the growth through the season. Several of the images show groups of line segments that were drawn blind. This was conducted as a warm up exercise to familiarise my hand and eye with the lines. Science describes this as 'motor priming' of the hand, encoding the line to motor memory, as occurs in learning a phrase to play on the piano.

Drawing as navigation

I explored navigation as an analogy for observational drawing. There are two distinct


Fig. 6.12 Drawings made while being eye tracked. Following fine detail of leaf

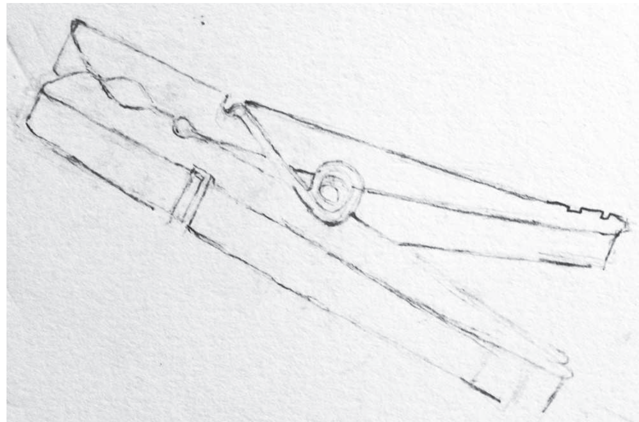


Fig. 6.13 Drawing of peg by Lucy Lyons, July 2013
.

approaches to navigation; using a map or using the environment. Using a map, you have the whole picture, and you try to match where you are to corresponding points on the map. You have to understand how the plan view with symbols translates into your egocentric view (normally an elevation) of the real world, e.g. what does a line representing a road look like from my point of view, on the road? In a way you imagine yourself on the map and in the world at the same time. Alternatively if you don't have a map, or you prefer not to use one, you can find your way within the environment, relying on an egocentric system by which you orientate yourself to the environment, keeping an eye on landmarks, or other markers, to constantly monitor and adjust your position in relation to these. This depends on knowledge of your physical environment and the desired relationships with it, and the maintenance of these relationships in order to reach their goal – this could be in relation to the sky, the sun, stars, the landscape. When using the map you have to have a grasp of the relationship between yourself, your current location and an imagined you on the map. The way-faring technique, relying on an awareness of where you are in the environment more closely resembles my drawing method; rather than refer to a map of the whole journey, which in this case would be provided by the external object, one relies on an on-going self-orientation as one progresses. In terms of orientation in the case of drawing the environment consists of lines just drawn and their counterparts in the world. Orientation entails checking that line segments drawn match those they mirror, and that they join together at the same angle. Going beyond the limits of the study of line drawing, shading can operate in the same way by matching shapes of areas of shading to confirm that the parts are accurately articulated.

Tversky and Suwa (2009) referred to these two systems as wayfaring and route finding. Route finding uses a map rather than the environment to reach the goal, so a representation of the whole journey is available. Whereas in wayfaring the navigator proceeds detail by detail, knowing that the goal will be reached because the details are correct, and will lead to the goal. Working with Tversky at Columbia University, doctoral student and educator Andrea Kantrowitz (PhD thesis submitted April 2014) is exploring the analogy between navigation and drawing, proposing that route finding is used for depiction while wayfaring for generative drawing from imagination, for discovery. She hypothesises that observational drawing more often uses a method akin to route finding, i.e. using a map, while 'drawing for discovery', for example to design, uses a wayfaring method. The discovery mode is used to innovate, design and think without an external object to draw from. Wayfaring entails the navigator possessing a bodily awareness of her position in and relationship with the world; knowing where she is

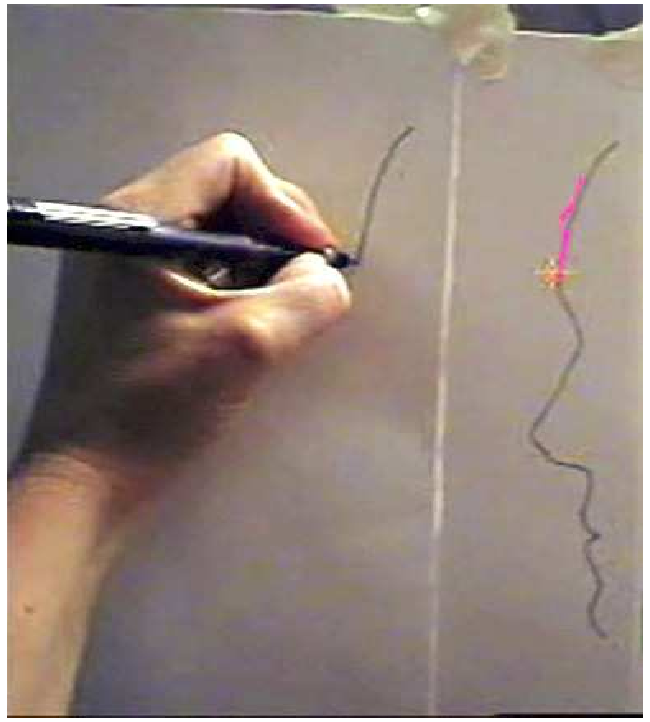


Fig. 6.14 Drawing blind, July 2013

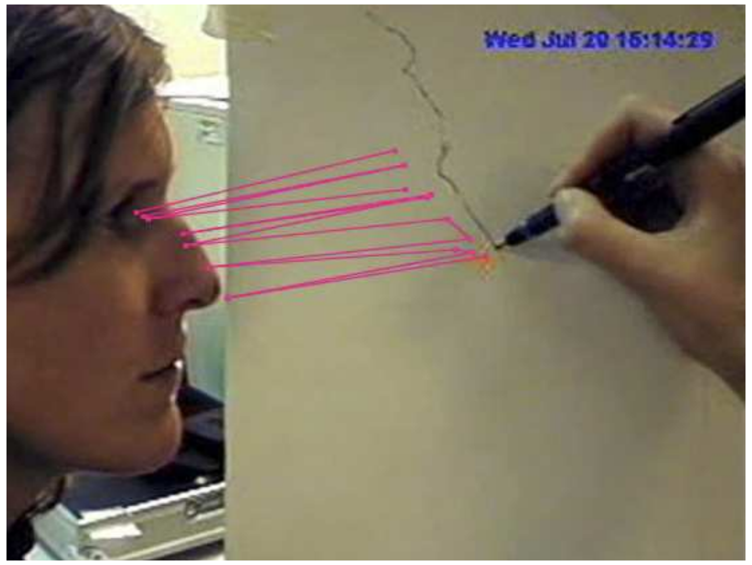


Fig. 6.15 Still of the eye path of Michelle Fava, drawing author's profile. July 2013

without looking at a map. She feels her way. It is a generational method, with the whole not yet existing, so the drawer has no possibility of using a route finding method. There is no map for the drawing.

In observational drawing an external map, in the form of the whole object-to-be-drawn, is available. So why not use it? Observational drawers often do, beginning by sketching-in an outline of the whole object, to anchor the drawing. Then they proceed segment by segment, detail by detail. An ability to switch attention between the whole and detail is posited as a marker of expert drawing skill (Fayena-Tawil, Kozbelt, Sitaras 2011, Chamberlain 2013). My method diverges from this, using a method more like wayfaring, where the drawer attends only to detail, attending to the relationships between details / segments and knowing that if they are precisely related and orientated an accurate whole will emerge. The practice of this way of drawing is like doing Sudoku puzzles, where one proceeds in small steps, and as long as you don't make a mistake in your reasoning you will succeed in solving the puzzle. Is this a more 'right brain' intuitive way of drawing? A more embodied way of drawing? It is akin to a blind person feeling their way in time around an object, and coming to understand what it is, and hence fits with Gregory's definition of vision as 'touch at a distance', and Nicolaïdes' instruction to imagine oneself touching the object-to-be- drawn.

My method gives a sense of emergence, that one has built the object piece by piece, and it fits together. This avoids the risk that the whole dominates, and that the details are distorted to fit into a whole – bringing us back to the question of conceptual bias and preconceptions about objects. Tchalenko and Kozbelt both suggest that visuo-motor encoding of line segments helps to avoid conceptual bias. My method implements this in teaching practice, using motor processes and attention to detail as explicit strategies.

My method proposes using the 'discovery' mode for observational drawing. What does this mean for the process? Fava filmed me drawing as a case study in her research (PhD in preparation) and defined my approach as 'additive'. Can we argue that it in some way becomes 'less cognitive', in the sense that it needs less thought and more action? Or rather that it is more physical, and that meaning emerges from action? It is more of a moment-by-moment inquiry, allowing the physical action to control the outcome, without looking, or predetermining, the destination. For me drawing has exciting moments when the lines link up, as explained above, showing that you are on the right track in terms of accuracy and relationships of parts. There is only one solution that works – if all the parts relate correctly. Drawing practitioner and researcher Lucy Lyons uses a method very similar to mine. (See

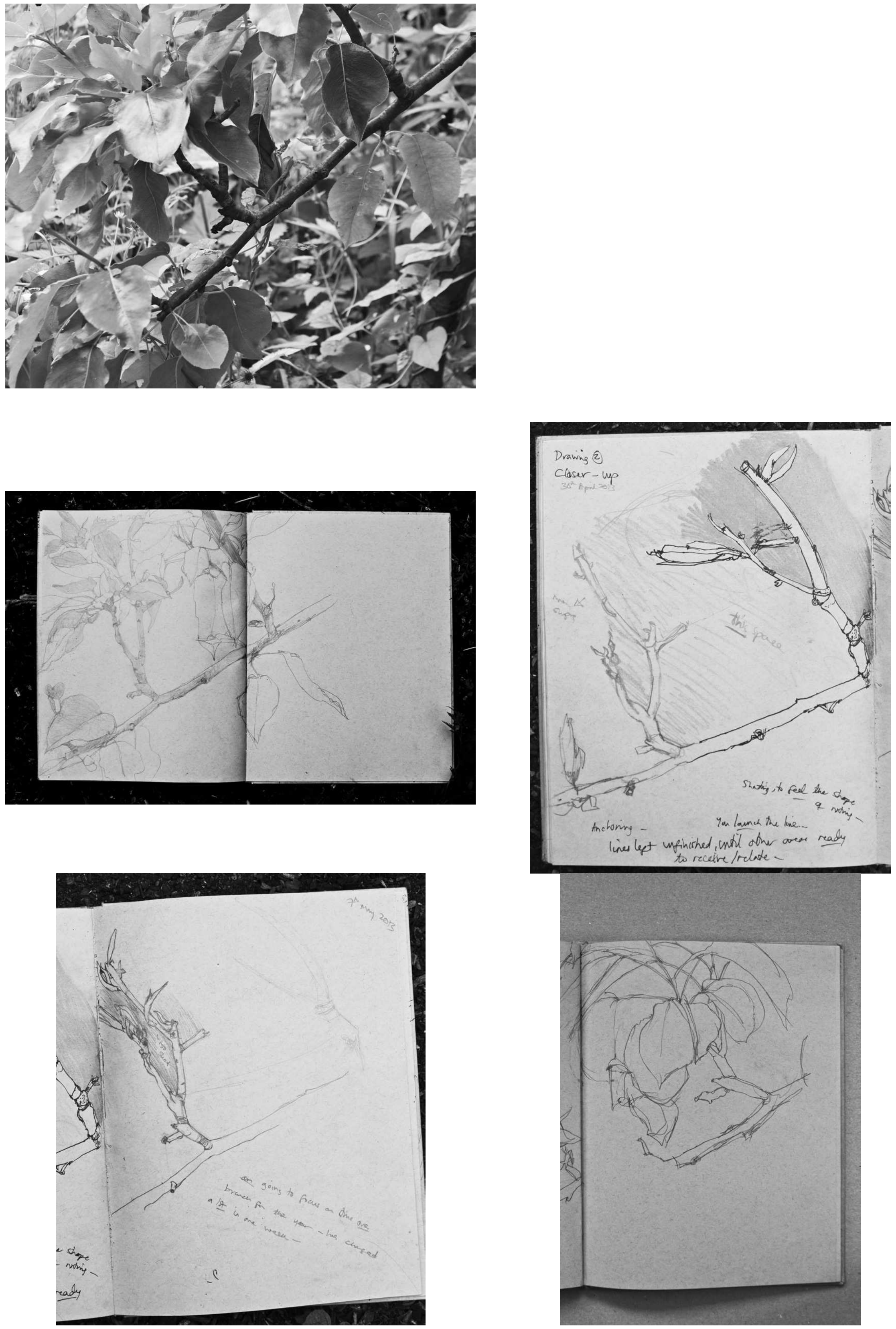


Fig. 6.16 Drawing Growth - Photo of pear tree, with observational drawings made 2011-2013

interview with author, Lyons 2013). As outlined earlier, she defines her drawing process as travelling along the line with her eye.

Living the line

I realised that I talk about, and feel, as though I am actually travelling along the line myself when I draw. This brings us firmly into the realms of embodiment, if we find that as drawers we are imagining our moving bodies to be the pencil – moreover with my method this moves from imagination into reality, because a part of our body, the eye, is literally travelling along the line as we draw. We are not, as Paul Klee suggested, taking the line for a walk, but rather walking the line. Encouraging the eye to travel slowly along the line, as my method does, may contribute to the feeling of being the line. When what is important is knowing how the lines relate to the just drawn lines, this bodily identification with the line becomes a way of understanding the movement of the line.

Target locking

One of the interesting questions that arose from my reflective practice was the question of target locking. Tchalenko frequently observed that people fixate on an end point on the paper, to draw to (Tchalenko and Miall 2009a p.372) implying that the line is planned before execution, with its length and trajectory projected onto the paper. However in my own practice I often do not select an end point for line segments, as it is not until more lines are drawn that the end point will be clear.

This suggests a different method, with the length of the line undecided and to be discovered through the drawing. Any one line relies on the articulation with other lines, not on an isolated ability to draw a simple segment to scale. We may find that experts can draw to scale and can orientate simple lines to the vertical if required, but this triangulating method offers an accurate checking mechanism, as the drawing proceeds, to anchor the lines. In practice if I draw a line too long another line will challenge it later on, by intersecting it before its end. The question at that point will be which line is right – is the second line at the wrong angle, or is the first line too long? The lines keep each other ‘in line’. Observational drawing in this way is a deductive process.

Tchalenko’s analytical decomposition of line segments into three elements fit with this. He defines these as shape (curvature), scale and orientation. These aspects are all investigated in practice by using my drawing method; the method itself constantly checks for errors, identified when line segments do not match / align with one another. By leaving the length of lines open and contingent, the first question relates to angle / orientation, for which I try to align and coordinate the eye and hand to launch the line at the correct angle to the vertical, horizontal, or in relation to another already drawn line. I then attend to the curvature of the line by drawing the line by synchronising the eye and hand. For me errors are more often made in terms of exaggeration of curvature, rather than angle of line. Obviously the two are interrelated as the curvature is about changes in orientation, however the orientation at the start of a segment is distinct from the on-going orientation of the line, achieved while drawing. Lyons stated that for her the pause functions as a space to re anchor herself to the object and to 'where she is' (Lyons 2013 24mins 4s). The initial orientation of the line comes after a pause, when assessment of previous lines will have occurred, and plans made for the next line to be drawn. The launching of the line is different from the on-going monitoring of the changes of angle as the line is drawn. Tchalenko believes that the visual shape of the line is encoded into a motor plan and then executed between a chosen start and end point on the paper. Related to this, he believes that the encoding of the shape is accurate without reference to the paper, but that getting the scale of the segment accurate and at the right angle is subject to error unless one looks at the paper to select a start and end point for the line. I propose that the travelling line method solves the problems of scale and orientation, as the line is embodied and easily drawn to scale and orientated. In which case looking at the paper need only check for the start point, and assess the lines once drawing for Tchalenko's three elements. By this method the end point does not need to be selected; it will be discovered by other future lines.

Lyons used the analogy of cooking from a recipe, compared to cooking from ingredients, analogous to ideas above about the navigation of drawing. The issue comes back to whether you draw from parts to whole or from the whole. The profiles of depiction and discovery drawing will be interesting to further explore, with the possibility of comparing brain activity and eye movements to test whether the analogy of route finding and wayfaring finds empirical support, and to develop our understanding of different ways and uses of drawing.

Finally this leads us to ask whether drawing is better framed as rooted in feeling rather than in vision. The next chapter discusses this in more detail, proposing a multi-sensory enactive framework for the practice and research of observational drawing.

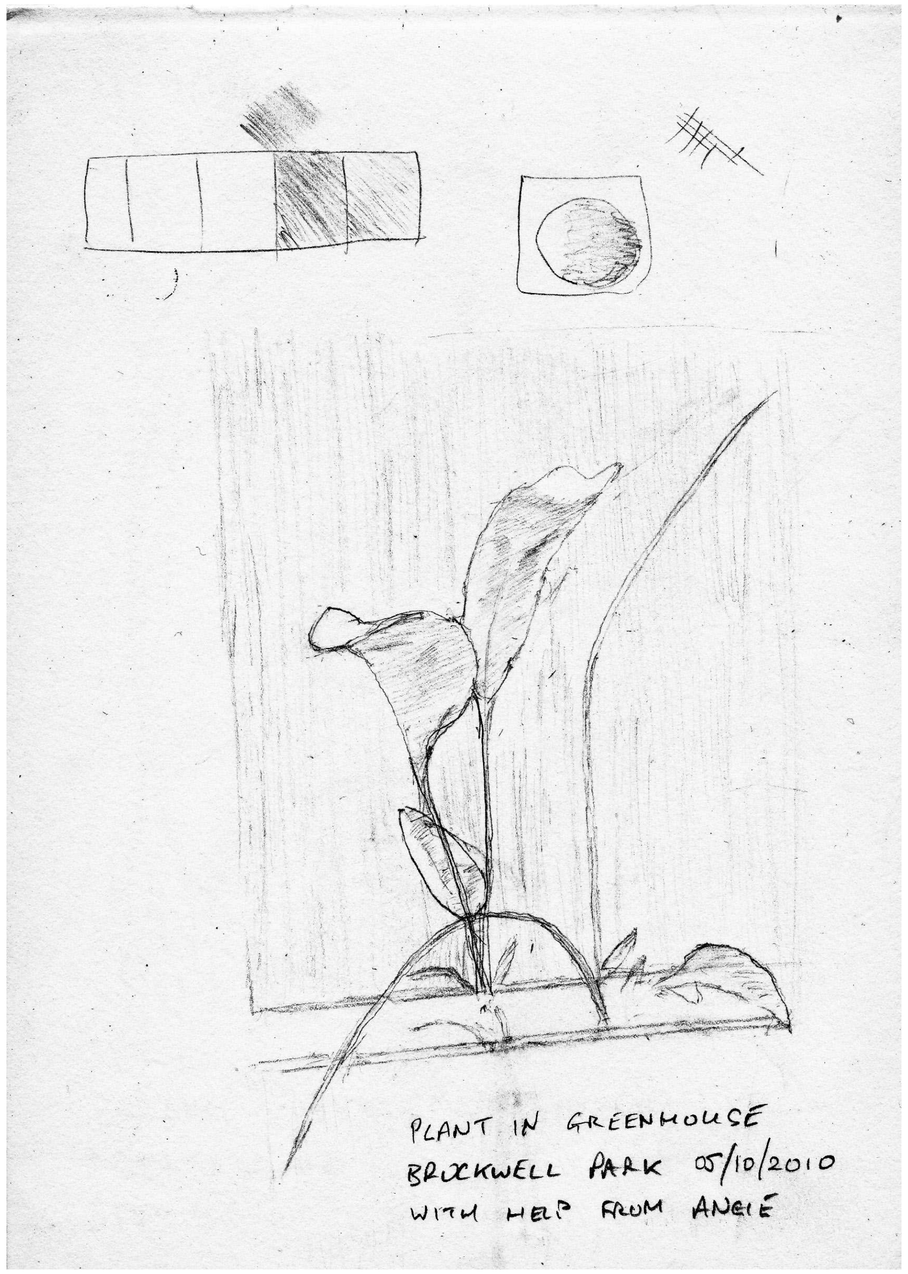


Fig. 6.17 Observational drawing by student K. 5th October 2010, Drawing Growth class

Student feedback

I taught several students during the study. K and P both identified as beginners. AH had minimal drawing experience. Below is some of their feedback on my teaching method.

I gave K what he claimed was his first ever drawing lesson. I used my method of connecting eye and hand. He writes of a sense of connection to the object. See fig 6.17.

He followed lines around the plant with his eyes, and drew the lines with his hand at the same time. He wrote :

> Many thanks for taking the time to start me off drawing last Tuesday. As promised here are some brief thoughts written after the session.
>
> I struggled a bit to get the contour of the leaf shape I was drawing to reflect what I was actually seeing in front of me. I quickly became aware of how it is necessary to establish a basic affinity with the drawn object if one wants to draw well. While drawing I was being led into a deeper or more complete way of seeing and experiencing the leaves of a plant i.e. the curvature, nuances of light and shade. I reflected on the fact that this heightened awareness is part of the visual artists' view of the world. I start looking at buildings, trees and plants with greater intimacy and detail. Colour, shape and illumination take on a greater intensity. The result can be a liberation from a previously held structural view of the world into greater freedom.
>
> Cheers (Personal correspondence, e-mail, received 11th October 2010)

Student P kept a diary of her experience of my teaching. Here are excerpts from her diary.

Drawing with Angie 5th March 2010

> Without looking - Challenging as normally look and look at paper, assessing and criticising. Had a sense of following the line and flow. Pleased with result of doing a small area as it looked quite 3d. I really looked intently at subject in a way not done before. (Personal correspondence, e-mail, received March 2010)

Student AH took part in a lesson with three students in February 2011. She wrote regarding eye hand synchronisation instructions:

> Eye-Hand section - I found this technique particularly exquisite and delightful - very peaceful. LOVED the feeling that the eye was like a pencil, and also LOVED the feeling like I was that pencil point ...all very meditative. I was very surprised, delighted and intrigued by the emphasis on process rather than result, and also by the very particular emphasis on eye-hand connection. It felt instantly meaningful and purposeful, and yet completely unexpected!,… there were time restrictions in the class, and I would have loved to incrementally go from this moment by moment being/drawing thing .... to portrait drawing. Even though I did not complete the process, I could sense how making the eye hand connection would completely transform the "grasping"/"capturing" enterprise of

> portrait drawing, into something far more interactive, (far more about "being" than "doing"?), and I could see that this technique would even introduce some kind of integration between subject and object.... (Personal correspondence, e-mail, received February 2011)

Finally, she commented that she found the method 'really quite beautiful, unique and effective.' (Personal correspondence, e-mail, received February 2011)

6.4 Discussion

The discussion reflects on the drawing method in terms of the relationship between perception and action, and considers its pedagogic and research applications. The method is explorative rather than depictive, offering an alternative motor-based way of drawing. In summary the instruction starts by exploring the theory and practice of everyday eye movements, progresses to practising drawing with the eye and hand, drawing blind i.e. keeping one's eye on the object, repeated drawing of a segment of line, to the complete method wherein attention is paid to timing and pausing; the eye glances at the original at the beginning and end of the each simple line segment, and uses the pauses to assess lines in comparison with the original, to check curvature, angle, position on the page and scale, and their interrelations.

A research method

The aim is not to make a drawing, but to discover things about the object and about perception, and to engage in a particular mode of looking and observation, only available through close communication between eye and hand. The final drawing, the outcome on the paper, may or may not contain evidence of discoveries made. Evidence may be found in the drawer's account of knowledge acquisition, and in their feeling of development of observational skill. There is a fine balance required between attention to parts and whole. In this case the drawing and observation of detail rather than whole is achieved through a focus on segmentation of lines in time and an awareness of movement. Methods such as Betty Edwards' similarly attend to parts to build up the whole, but by focusing on a cognitive shift rather than motor action and rhythm. While many practitioners sketch an outline before drawing my method proceeds from detail to detail, allowing the whole to emerge from the parts. I propose that this method has a particular strength for research, as it acknowledges that the percept changes through the progression of the drawing, and allows the whole as an articulation of the parts to emerge on the page. Entailed in the process is exploration of perception itself. However work on sketching suggests that underdetermined ambiguous drawings allow room for amendment during the creative process (see Suwa & Tversky 2009, Tversky 2011b), so processes where a provisional outline is drawn, to be altered, also fit into this model of research drawing. In general though drawing that starts from an outline and fits the parts into the whole is more illustrative and less a research method, unless the whole is acknowledged to be contingent and a way is found to prioritise the articulation of the details.

Cognition and action

Van Sommers' statement that copying is a translational and constructive process rather than a 'matching of perception to action' (1984 p.50) resonates with Merleau-Ponty's description of the artist's net-weaving, fish-ignoring way of looking. This leads us towards the proposition that observational drawing sits between sense and action, embracing both, with an especial connection between the eye and hand, a good exemplar of the new paradigm of enactive vision and perception in action. My instruction looks for direct and appropriate translation skills, entertaining a more fluid and integrated view of the play between senses and perception and between the eye and the hand. Does the hand see?

> Without practice this kind of sensation is rather confused and dim; but if you take men born blind, who have made use of such sensations all their life, you will find that they feel things with such perfect exactness that one might also say that they see with their hands. (Descartes 1985, p153)

Descartes' insight about touch is beginning to be supported by scientific research of sensory substitution. The hand can anchor perception, and teach the eye; they can search together and instruct one another, as acknowledged by artists Bridget Riley (2009) and Ruskin (1971).

There are two points to make about the instruction in terms of the division of cognitive and executive phases: firstly how this separation and explicit explanation works well as an instruction, and secondly how it can be used a model for further scientific testing. It has been difficult for psychologists to break down the complex intertwining of processes involved in drawing. The contrasting roles of the eye in the two phases may facilitate studies of brain activity during drawing.

As a first step towards learning to draw, the method divides cognitive and executive elements of observational drawing into two distinct phases. Paradoxically, after arguing that perception and action are hard to separate, the instruction can be seen as an attempt to split the drawing process into two distinct phases, one executive and one cognitive, i.e. drawing, and not drawing, wherein the thinking takes place while not drawing, while pausing. This is given as an explicit verbal instruction to the student: to think only about coordinating the movement of eye and hand while they are drawing, and to conduct visual assessment while they pause. On a micro-level, the eye moves and pauses during each phase of movement – the eye pauses and fixates and then saccades to another spot. The instruction establishes a clear division between drawing and assessment behaviour, and distinguishes the role of the pause. The model is potentially useful for empirical research, because it has these distinct phases of action with specified function. These could be compared, and tested for brain activity.

I hope that this drawing method may open up the question of how drawing practitioners measure segments of line with the eyes and hands. Lyons' awareness of the eye travelling along the line and connecting with the hand fits with my method and the idea of a reliance on the synchronisation of eye and hand. When interpreting their fMRI findings Miall and Gowen stated that we do not know whether these visuomotor translation processes of drawing involve encoding of spatial coordinates (a spatial map) or of an imagined action (a motor plan). I suspect that drawers use a range of encoding processes; some, like Lyons and I, move the eye along the line, and others rely on locating an end point of the line, and then position a target on the paper for that end point. For future study it would be interesting to examine the differences between the method wherein the eye travels along the line rather than selects start and end points, stemming from Mialls' open question about what the fMRI data tells us about visuomotor encoding.

Chapter 7 Discussion

7.1 Introduction

This final chapter articulates findings from the strands of research and shows how they led to the development of an enactive and scientifically-informed framework for the practice and teaching of observational drawing. The proposition that emerges from the study is that drawing can usefully be framed as a conversation between the eye and hand, and that this offers a powerful way to think about drawing, and to draw. The drawing method is for research and discovery, rather than depiction. By this reframing, observational drawing is understood to be a perceptual tool; one draws for perception, not from perception. Considering observational drawing as a bodily conversation opened up the exploration of how movement affects perception, and of how we think and understand; how we figure things out. It also allowed an alternative approach to practice and teaching, hinging on movement rather than disembodied vision. In the light of enactive theory, the answer to the research question is that drawing not only affects perception, but is itself a mode of perception, using both the eye and hand to achieve an extra-ordinary way of understanding structures of appearance and relationships. The hand contributes to visual perception because of the particular reflective nature of drawing as a skill. The argument is made - through study of recent scientific findings, vision science and enactive perception theory, and reflective practice - that observational drawing requires precise synchronisation and a two-way communication between the eye and hand. The enactive view allowed a questioning of the perception/action dichotomy, and consideration of drawing as a multi-sensory perceptual process. Reflective practice pointed the research in the same direction, prompted by a personal sense of the inadequacy of much of conventional observational drawing pedagogy, a doubt about the role of visual memory, and a intuitive conviction that the hand plays a decisive yet unacknowledged role in perception for drawing.

The recent scientific findings of psychologist Chamberlain (2013) and Tchalenko were found to be of particular interest in relation to my practice-based findings. Tchalenko's current study (Tchalenko et al. 2014 in press) has strengthened the argument that motor planning and encoding play a role, and Chamberlain's findings from experimental and empirical study support this view, challenging the idea that observational drawing relies on mental imagery, internal visual representations and memory.

The study establishes that observational drawing is a powerful tool for thought, understanding and research, and that understanding how to articulate lines is a transferable skill, useful for living in general, and not confined to art production. Drawing is both a metaphor and a tool for living. Ingold suggests that 'life lines' are open-ended, like Gregory's contingent gaze, explorative and curious rather than predestined to end at a set point. To restate, Ingold holds (as quoted here on p.23) that drawing does not:

> ...seek to replicate finished forms that are already settled, whether as images in the mind or as objects in the world. It seeks, rather, to join with those very forces that bring form into being. Thus the line grows from a point that has been set in motion, as the plant grows from its seed. (Ingold 2010 p.2)

While some drawing practitioners draw to depict, the method I propose leaps into the world, follows lines, rather than heading towards a visible goal. The interesting question remains, whether we, as Tchalenko thinks, tend to 'target lock' or, as Ingold and I propose, we wander along lines.

The literature review revealed gaps in knowledge and method, notably in communication between drawing science and observational drawing pedagogy, and suggested research avenues for the study; to interrogate the relationships between eye and hand, between perception and action, and between science, philosophy and pedagogy. Findings from the Drawing and Cognition Project and the quantitative study documented in Chapter 4 demonstrated that the move from novice towards expert drawer is characterised by temporal synchronisation of the eye and hand, with more pauses, more line segments, and more time spent drawing. These findings, and subsequent practice led to an argument for the repositioning of observational drawing within art practice, in wider education settings, in research, and within contemporary enactive theories of perception.

7.2 Contribution

The thesis contributes by applying new findings from cognitive science of drawing to observational drawing practice and pedagogy, within an enactive framework.

The key findings of the thesis are:

That the eye and hand converse in a deep and detailed, extra-ordinary way, to allow observational drawing.

That observational drawing can be taught via movements of eye and hand, rather than by teaching cognitive strategies.

That observational drawing can be defined as a mode of perception, rather than depiction.
That observational drawing can be employed as a research tool, with great potential for discovery and knowledge production, about the visible world, relationships, thought, perception and action.
The central contribution is the explorative drawing method, underpinned by the proposition that drawing can be usefully framed as a way of perceiving things, a multi-sensory approach to observation, and that this way of engaging and practising can change how we experience life.

7.3 Summary of findings

Recent scientific findings from the Drawing and Cognition Project were framed into a working model of expert drawing behaviour, for application in drawing practice and teaching, and were used in the subsequent reflective study. In Chapter 4 we found from the Betty Edwards case studies that experience led to more complex eye hand interactions, as shown by the graphics from video time lines, and supported the working profile of expert drawers: more segmentation, taking longer time, pausing more and for longer. The results indicate that significant changes occurred in all the participants after only 5 days of training and practice, suggesting that five days of drawing practice and training had an impact on behaviour and hence on means of perception. Changes occurred in times spent drawing and pausing, the number of dwells on the paper and original, the number of line segments drawn, drawing speeds (slower), and in accuracy of copying. Improved accuracy might rely on any or all of the following: taking longer, concentrating harder, looking between the original and the paper more, looking in a different way, more efficient or appropriate encoding and transfer of information from eye to hand, knowing where to look and when (e.g. comparing key elements such as angle of turning points) using pauses to assess, improved visual discrimination (see Kozbelt & Seeley 2007). Drawers who can 'perform' an accurate copy at first attempt may use a method entailing continuous assessment, monitoring for errors before or just as they occur, allowing for correction. This could be defined as a 'just-in-time' strategy, akin to those used for execution of skills such as driving, playing cricket and playing piano, as referred to in Chapter 2 section 2.7. This avenue is worth exploring further, in recognition of the range of possible approaches to drawing.
In addition there was evidence in case study A of the development of a distinctive sequence of behaviour, timing phases of drawing and pausing, with gazes between the original and paper. This informed the development of a teaching method based on training students

to move in this way, supported by verbal explanations about visuomotor processes and information about what experts do differently in order to draw accurately. The development of longer pauses begs questions about cognitive activity taking place during pauses, and the interaction between drawing, pausing, planning, executing and assessing work, all of which were explored later in the project through drawing practice and the development of drawing instructions.

Tchalenko and Mialls' hypothesis about motor planning and encoding gave a direction to the practical enquiry, with the key question being 'to what extent can blind drawing be used?' Observing how students transferred their gaze between original and paper led to the question of how, if the hand is guided by a motor plan, the eye supports the execution of that plan. The answer that emerged was that the eye helps the hand to position itself correctly for the start and end of each line and for angles between lines. This was used for development of a drawing instruction method.

The emerging idea was that accurate drawing depends on coordination of several temporal aspects, particularly knowledge of when it is necessary to look at the paper. Analysis of data suggested that all participants improved in accuracy of positioning of the line on the page, in determining the length of the line, and in the character of the line, but it was not possible to analyse the accuracy of segments. There were various types of errors (inaccuracies) made by the participants. During the analysis it became clear that an error may stem from an attempt to correct a previous error. This meant that caution was necessary in positing causes of errors, and also in isolating simple segments of lines for comparison. Because participants were drawing with felt pens they did not have the opportunity to correct errors with an eraser, and sometimes chose to correct with a compensatory line.

It may be that the single factor of drawing more slowly improves accuracy and/or that pausing for longer and more often plays a role. There may be several different ways to achieve accuracy. Cohen and Bennett's attempt (1997) to isolate factors affecting accuracy is relevant here. They defined the elements of drawing into motor coordination, the decision-making process, misperception of his or her work, misperception of the subject / thing to be drawn. As argued in Chapter 2 their conclusion that misperception of the thing to be drawn is the sole cause of inaccuracy is not convincing, because of their inductive method and the question of whether elements, if indeed appropriately categorised, can be isolated in this way. How attention, planning, procedural knowledge and patterns of eye and hand movement function within any of these conditions is not specified, and it may be that another factor entirely, or a combination of factors, is the cause of inaccuracy. A simpler copying task in conjunction with accuracy measures would perhaps reveal more about how people learn to copy.

Chapter 5 developed an enactive theory of observational drawing, which provided a framework for the development of an enactive drawing method. The theory proposed that the hand and eye both contribute to the perceptual task, and need to learn to communicate and synchronise movement for accurate observational drawing to be possible.

Chapter 6 found that observational drawing can proceed, and be taught, by attending to movements of eye and hand, and by using a line-following method. This was shown to be akin to Ingold's wayfaring approach to life and research.

It proved effective to turn the perception to action paradigm on its head. Rather than teaching cognitive strategies the method developed asks students to attend to motor movement, and its role for perception. The method is guided by the belief that eye and hand both need to learn new ways of moving and interacting for drawing, leading to the idea that the eye and hand learn from one another and learn to communicate, like instruments in an orchestra.

The drawing method deals with conceptual bias in a new way, using movement and coordination to attend to details, building up the whole, and using the hand to dispel any misperceptions the eye may have.

Observational drawing was identified as a reflective research practice, of particular use in the study of perception and vision, and the complex relationship between perception and action. As Focillon put it, the hand constructs vision, gives body to vision, and 'enlarges its perspectives' (Focillon 1989 p.180), and as Ingold writes of drawing (2010), it creates rather than replicates.

WIth regard to blind drawing, it is fascinating to think that the drawer discerns, or arguably creates or imagines, a line and doesn't let go of it until she has drawn it. Chapter 6 outlines how my reflective practice and the practical application of Tchalenko and Miall's findings led to a similar conclusion about blind drawing as an effective strategy. This stemmed from reasoning that if one only needs to look at the paper to anchor the line segments on the paper and in relation to the drawing, then the participant has the opportunity to keep her eye on the object more, which will potentially help with a direct visuomotor encoding.

Chapter 6 pursued this idea, basing drawing instructions on coordination of movements and explanations to students of the 'new science of drawing', especially the information that novices and experts alike can draw segments of line accurately without looking at their drawing and the paper. Chapter 5 developed a theoretical base for this new drawing method, considering Tchalenko's hypotheses about blind drawing, visuomotor encoding, segmentation and timing of eye and hand movements within the framework of enactive perception theory, and discussions about internal representation systems and visual imagery.

The thesis shows that the drawing eye works with an intelligent 'seeing' hand. The thesis has also shown that scientific research has, in the last couple of years, begun to support the view of many practitioners, that drawing transforms how we see things. Chamberlain (2013) and Likova (2013) found evidence of structural brain changes associated with drawing practice. Importantly, drawing is being researched not just as a fine art practice, but as a manual and coordination skill – an art, a craft, a path and a tool for thought.

7.4 Progression

I began my research in 2006. The study took an unexpected turn after the first two years, when I returned from a year off with illness, and my supervisor John Tchalenko retired from our university. I had began working with him in the Drawing and Cognition Project at Camberwell with the aim of running scientific tests to explore some of my intuitions and unanswered questions about how observational drawing 'happens' – how it plays out, and how it works. In the event, the only quantitative studies I carried out were my case studies of Betty Edwards' students in Santa Barbara, and assisting Tchalenko with his eye-tracking research. I had the opportunity to analyse his data, and to interview his eye-tracking participants, which helped me to gain insight into various aspects of the drawing process. In those early years of study, Tchalenko commented several times that the next step was for someone to put his findings into practice. After observing Edwards' students in 2009 I took this step, by starting the Drawing Growth project at Brockwell Community Greenhouses. This gave me the chance to try out different methods of drawing and teaching. At the same time as trying to put Tchalenko's findings into practice, I was searching for an alternative to allocentric drawing methods, that employ spatial measuring techniques that seem to distance us as drawers from the objects we are engaged with. I began to view observational drawing as a conversation between the eye and hand, as a way to explore how we communicate with ourselves during drawing, and to teach it accordingly. Hence the idea of conversation became an important metaphor, and a paradigm for teaching. Framed as a conversation with yourself, drawing functions in triangle with self and world.

Before I began the research I had read Merleau-Ponty's thoughts on perception and phenomenology, and contemporary interpretations of his ideas about embodiment and enaction, particularly the writings of Alva Noë. During my research the work of anthropologist Tim Ingold proved a revelation, as his holistic view resonated strongly with my developing drawing theory, emphasising an open-ended questioning approach, more akin to wayfaring than to route finding with a map. From reading research on navigation techniques, I had developed my own argument that drawing could be either wayfaring or route finding, so to come across Ingold who had thought deeply about the same concept was inspiring and useful. Unlike many writers interested in embodiment he writes specifically about drawing and particularly about lines, so he registered as someone dealing directly with the same issues as I. His writing informed the latter stages of research and the writing-up of the thesis. Ingold points out that drawing takes time, and that there is a gulf of difference between drawing a straight line between two points, and following the line freehand. This directly relates to the unaswered question of whether drawers 'target lock' and pull the pencil to an end point that is chosen and locked onto by the eye, or, as with my method, draw the pencil along the line, without a predecided end point.

In 2011, soon after forming the Drawing Growth project, with Tchalenko gone and minimal contact with scientists (with access to research papers restricted by being based in an Arts University) I began talking to other interdiscipliinary Ph.D students researching drawing and cognition. The work of Andrea Kantrowitz (Teachers College, Columbia University, NYC) and Michelle Fava (Loughborough University) was particularly connected with mine, and our transatlantic conversations led to a symposium in New York at Columbia University, and then to the formation of the interdisciplinary research group, International Drawing and Cognition Research (IDCR). This meant that I began to make wider and direct contact with the scientists, thinkers and practitioners working in my field. This was a turning point, as it enabled me to discuss issues with other like-minded researchers, and to access research papers. To date we have run three annual Thinking through Drawing symposia, two in New York, hosted by Columbia University and the Metropolitan Museum of Art, and one at Wimbledon College of Art, London. Thus conversation became central to my methodology, both in the sense of the conversation between the eye and hand, and of dialogue with a wide range of experts and practitioners in my field, across disciplines. The IDCR group has published several papers in books.

By the end of my PhD study I have found an enactive theory, as propounded by Ingold and Noë, that accounts both for my experience of drawing and of living, and fits with current scientific findings about perception and action. I am very grateful to John Tchalenko for leading me to attend to the hand as well as the eye. At the start of the project my proposal was solely about the eye, and how we look at gaps between things, with no consideration for the role the hand might play in the process. His approach 'opened my eyes' to the complex conversation between eye and hand. Thanks to him, the enactive underpinning provided by Ingold and Noë, Gregory's account of the limits and powers of vision, I was able to develop an alternative way to draw, which can now be explored by drawing scientists, practitioners and teachers.

7.5 Reflections on methods

The study asked how the act of observational drawing transforms us, how we come to see things differently. To begin to explore this question the research sought to characterise drawing as comprehensively as possible, by reviewing current literature and findings, by contributing new findings on eye and hand movement and how drawing 'plays out', and by searching between the lines, in the world and on the paper. As part of the enquiry practical exploration of temporal and spatial aspects of observational led to the development of a new method of drawing, which was considered to be a form of perception, akin to vision but augmented and fine-tuned by the hand.

The interdisciplinary methodology, that used drawing to explore drawing, connected new scientific models of expert drawing behaviour with enactive perception theory and observational drawing practice and pedagogy, enabling a new perspective on observational drawing, and its relationship to perception. The thesis aruges that the hand plays a leading role in the drawing process, and proposes a way to teach the fine-tuning of perception and action, informed by these ideas.

My methodology explored the use of drawing as a research tool, and the use of conversation and collaboration, both as a way of communicating between eye and hand, and between researchers across disciplines. This included working with Tchalenko in the Drawing and Cognition Project, and discussions and collaborative writing and drawing with Fava and Kantrowitz, my co-directors of International Drawing and Cognition Research.

Interdisciplinary conversations and collaborations

Initially I planned to conduct scientific experiments about drawing, to find out what is beneath drawing. However, the methodology that emerged was one of translational research, applying scientific findings to pedagogy and drawing practice. My approach to interdisciplinary study moved from a methodology combining science and drawing practice to the view that working collaboratively with scientists, rather than trying to do science, was the best way forward. The IDCR group offered a framework for this, with researchers from a wide range of disciplines exploring ideas together. This way of working recognises the value of expertise and specialist skills from different disciplines employing different methodologicial approaches, and collaboration that allows conversations that modify perspectives.

At the start I did not seek to locate the research in terms of contemporary fine art drawing practice, except in the field of observational drawing, however by completion I wanted to present a case for observational drawing as an embodied practice, with more in common with gestural and performative practices than previously acknowledged. This view became possible thanks to recent findings in cognitive science about movements of drawing and perceptual processes.

Study of expert drawers and longitudinal study of drawing students will significantly contribute to the research domain of brain plasticity and learning, and, through our interdisciplinary collaborations and communication, to the practical educational application of new knowledge about drawing and cognition. Importantly, the methods and thesis have found a place in contemporary interdisciplinary debate, where drawing, observational and other, is under pressure to locate itself in relation to new technology and to the requirements of academia and education. Networks such as International Drawing and Cognition Research and the Thinking through Drawing symposium series are at the forefront of this debate about drawing in the 21st century, with particular focus on embodied practices, tool use and and how these change our perceptions of our world.

Drawing methodology

The methodology developed its own meta-levels, wherein drawing was used to think about drawing, to reflect on drawing (by drawing drawing), and to draw thoughts. Many of the drawings made were 'thinking on the page'. These drawings do not necessarily communicate to others, but were a 'figuring out' progress, a self-communication. The drawing often revealed something to me that I had not been aware of or thought of before. This was particularly the case when I tried to draw timelines and models of how drawing plays out. This experience also occurred during observational drawing, as a process of figuring things out about the object, and, on a metalevel, learning about drawing. The affordance of the paper for spatial thinking and as external memory served to extend my capacity for thinking and the potential for discovery. In this way my observational methods are more relevant to contemporary research practices, rather than depiction goals.

The findings and writings of Barbara Tversky, a member of IDCR, underpinned my use of drawing as a thinking tool, as evidenced in numerous sketches, diagrams and maps that supported my thinking and now support the thesis text. My use of drawing, both observational and conceptual, developed over the project, further revealing its potential for discovery and communication. Of particular value was the development of a semi-linear form of annotated drawing, that avoids the pitfalls of radial mind maps with ambiguous hierarchy and order, whilst allowing more elbow room than conventional text, letting the reader follow one or other path, while still following the same overall thread. This exploration of the role of drawing in thinking, its function in creativity and problem-solving, and its role in visual literacy are all of relevance for how we communicate globally, and for the complex requirements of image-reading in 21st century.

There is much evidence that moving the body helps us to think (Tversky 2011b, Kirsh 2013) and the methodology emphasises that observational drawing is a way of moving.

Quantitative methods

In addition to providing data from the three case studies, the research represents a first step in developing appropriate longitudinal methods to track behavioural and perceptual changes related to observational drawing practice. The study began to develop methodologies for within-participant studies designed to measure accuracy, and for translational research that contributes knowledge for perception and drawing research and interdisciplinary study.

Drawing is becoming recognised as a powerful cognitive and perceptual tool, across disciplines in education, business and social and health care. The next step beyond this project is to delve deeper into the relationship between the eye and hand, to both inform perception theory and to underpin arguments for the usefulness of drawing practices. It seems worthwhile to continue the exploration of line drawing, and of the relationship between the eye and the hand, perhaps to discover, among many things, whether a) we have pencils in our brains b) Bridget Riley has an eye at the end of her pencil, and c) Ruskin was right to claim that drawing can lead to understanding of other observational drawers such as Leonardo or Titian. Ruskin stated that watercolourists '...must forever remain blind to the refinements of such men's pencilling and the precision of their thinking.' (Lawrence Campbell,.in Ruskin 1858/1971 p. vii).

The use of frame by frame analysis of video footage, combined with development of software to measure accuracy of line drawings, proved a useful approach for elucidating the physical process of drawing, especially the interaction of hand and eye. Testing of scientific findings in drawing studios and the field led to new questions and the design of a new cognitively informed drawing instruction, as well as a model for further scientific study.

7.6 The future

Target locking versus line following

Entailed in my method is a proposition about how the eye moves during drawing, suggesting that line-following may be a viable strategy, as opposed to target locking. Tchalenko found that experts tended to employ target locking; selecting, by eye, an end point for a line segment before drawing, locking the eye onto that point on the paper, and drawing the line to this point. My method uses an alternative approach, with the eye and the hand both tracking the line, in time. This question about the micro-movements of observational drawing remains unanswered. To my knowledge there has been no investigation of this and there is little evidence of practitioners using my explorative line-following wayfaring method. I hope that my method will receive attention from both pedagogy and science, and future eye tracking and video observation will reveal more about slow eye movements. The study in the pipeline, with psychologists from IDCR to conduct longitudinal research of the effects of drawing practice on perception, will hopefully further develop my research methods and test my drawing method.

Seeing things differently

I wanted to find out what might underpin an experience of 'seeing things differently'. I am acutely aware of what I have not studied and not found out: how the pencil as a tool may affect perception (for example, its sharp point), what happens when we draw moving things and the many uses of this way of drawing to record and track movements, what is going on in the brain while we draw and how the brain may change structurally as a result of drawing practice.

Although Perdreau & Cavanagh (2013) found no evidence of what has become called perceptual advantage (see Kozbelt and Seeley 2007), we still have numerous accounts of drawing practitioners saying that the world looks different to them as a result of drawing practice. Perdreau and Cavanagh's sample group was of artists, not specifically drawing practitioners, and participants self-defined their level of experience of observational drawing. From the view that drawing is a perceptual process involving the hand, is it not surprising that when you remove the hand from the process, the drawer may revert to a more everyday form of visual perception, using the eye alone. One of the points, and powers, of drawing is that it is an alternative approach that allows us to 'see more'. This does not mean that when we are not drawing we see in some sort of drawing mode. Although, my personal experience, and that of my student K, testify to the presence of a mode of perception characteristic of drawing that can permeate into the rest of everyday life. My anecdotal experience of perceiving a human face as a line drawing, rather than as an intelligible speaking person, demonstrated this effect. It remains to be seen whether any empirical evidence for this exists or will be found. Chamberlain's recent findings are, to my knowledge, the first set of results to suggest that altered brain structure correlates with drawing experience (2013). Also, Chamberlain made the important distinction between drawing practitioners and artists in her experimental tests. She distinguished between artistic and drawing ability to '...determine whether drawing or artistic ability in general induces a heightened perception.' (Chamberlain 2013 p.67). This led to interesting results, especially her finding that drawers, compared to non-drawers, have enhanced local perceptual processing, i.e. perception of detail, while artists, compared to non-artists, do not (Chamberlain 2013 p.183). This is certainly an area that needs further attention, in order to look at what is particular about observational drawing as distinct from other fine art practices. Rather than studying artists and art students generally, it would be worth studying professional observational drawing practioners, such as court artists or street portrait artists, and others who have consistent numbers of hours per day, week and year that are spent drawing from observation.

There is a case to be made for testing how perception is affected during the action of drawing, compared to testing perception using the eye alone, while not drawing. Perdeau and Cavanagh's (2013) rationale was that drawing execution should be excluded from perception tests, but I suggest that it should be included, to explore possible differences between intense looking and looking with drawing. This may reveal that drawers have perceptual 'advantage' while they are drawing, but that this does not necessarily translate into visual perceptual skills while not using the hand.

The position of drawing in the 21st century is of intense interest, and importance, across disciplines. Researchers are beginning to appreciate its role in thought and problem solving. Visual communication and methodologies are used increasingly, with the growth of international online platforms and a developing appreciation of creative, non-verbal and lateral ways of thinking. It is vital now to reassess and locate observational drawing in fine art practices, education across disciplines, academic research practices and in perception research. Drawing theory that is underpinned by contemporary cognitive science and embodiment theory has potential to expand how we use drawing, as well as how we understand it. The deepening characterization of motor and cognitive processes in observational drawing will contribute to the argument for the use of drawing in education and research, across disciplines and professions.

Finally, we have learnt from the quantitative and practice-based reflective study of movements of eye and hand that observational drawing practice can transform us; drawing can teach us how to draw, new ways to perceive, to observe, and to live the line. The thesis demonstrates that observational drawing is a perceptual process requiring fine-tuning of the eye and hand, that new ways of teaching drawing can be developed on the basis of new findings from cognitive science and enactive philosophy, and that connecting theory from science and pedagogy can deepen our characterisation and understanding of observational drawing.

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Appendices

Chapter 1

Appendix 1

1 (a)	Map of members of IDCR 2011 and their research interests

Chapter 4

Appendix 4

4 (a) to (o)	Accuracy measures of participants' drawn lines from day 0 and day 5 compared to the original
4 (p)	The original line, with landmark points used for computational analysis
4 (r)	Raw video footage: Participant A day 0.mov (see DVD)
4 (s)	Raw video footage: Participant A day 5.mov (see DVD)

Chapter 5

Appendix 5

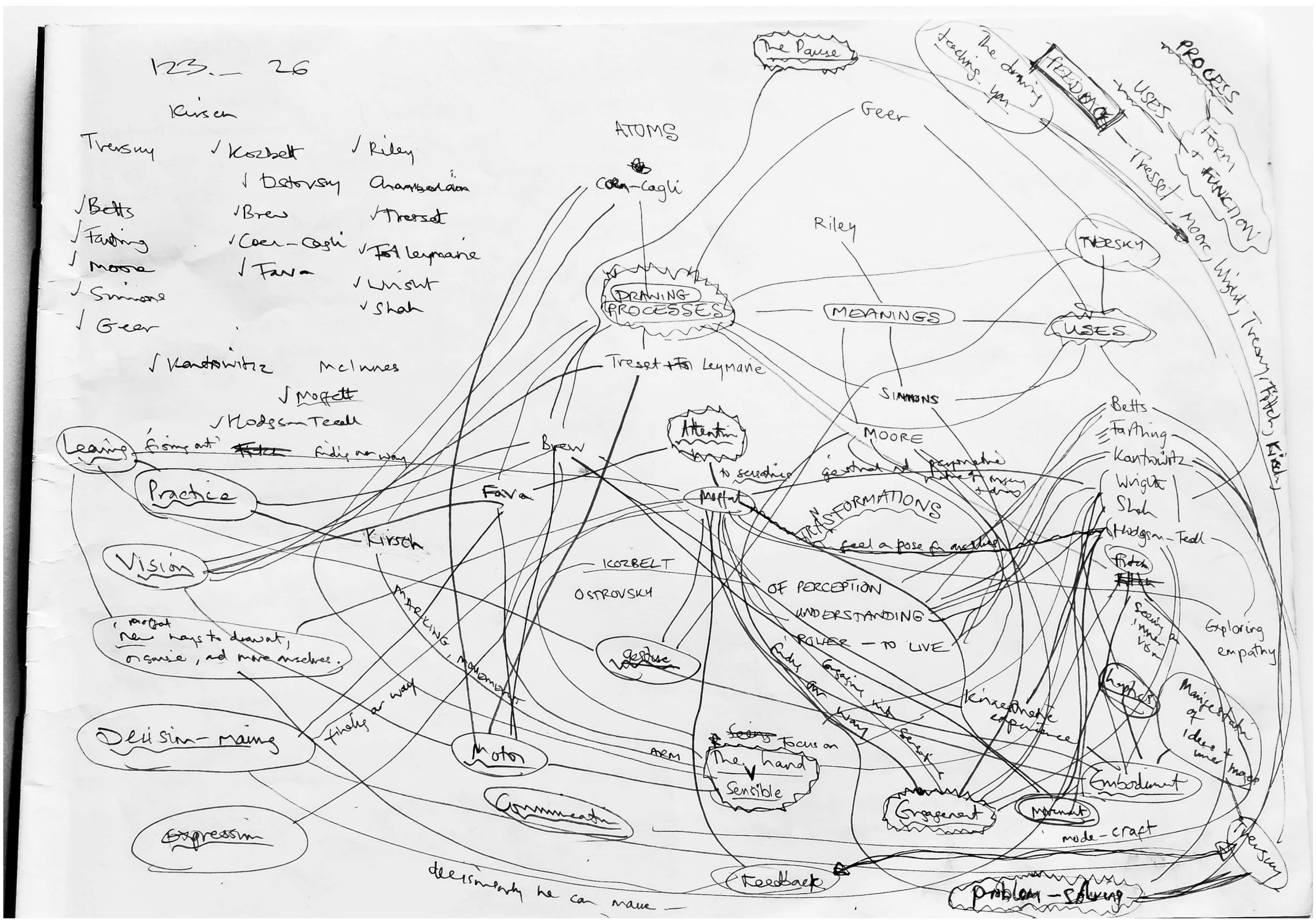
5 (a)	High resolution scans from section 5.2 (see DVD)
5 (b)	2 video interviews with Camilla Brueton (Brueton 2014a, 2014b) (see DVD)
5 (c)	5.2 Annotated drawings .

Chapter 6

Appendix 6

6 (a)	Video interview with Lucy Lyons (Lyons 2013) (see DVD)
6 (b)	Video of author drawing self-portrait (see DVD)
6 (c)	Video of author drawing eye line segments (see DVD)
6 (d)	Audio of drawing lesson, Metropolitan Museum of Art, NYC, October 2013 (see DVD)
6 (e)	Self-portrait by author, 2013
6 (f)	Observational drawings by author 2006-2014 (see DVD)
6 (g)	Conceptual drawings by author 2006-2014 (see DVD)

Apppendix 1(a) Map of members of IDCR 2011 and their research interests



Appendix 4(a)

Accuracy measures of participants' drawn lines from day 0 and day 5 compared to the original

File	Start	Supragla-bella	Nasion	Nasal tip	Naso-philtral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin de-pression	Chin apex	Chin inflection (jawline)	Cervical point	End	Path length in pixels	In mms
ORIGINAL LINE	0	0.174328	0.219104	0.421493	0.469254	0.496716	0.528955	0.58806	0.653731	0.695522	0.797015	0.846567	0.896119	1	837.5	435.5
A day0	0	0.092593	0.165165	0.290791	0.352352	0.389389	0.427427	0.540541	0.657157	0.731231	0.817317	0.866366	0.913914	1	999	519.48
A day5	0	0.146866	0.192836	0.393433	0.449552	0.468657	0.49194	0.572537	0.660896	0.687761	0.825075	0.859104	0.900299	1	837.5	435.5
K day0	0	0.131671	0.179052	0.343641	-	0.419451	0.446883	0.546135	0.649377	0.704239	0.802993	0.850873	0.899751	1	1002.5	521.3
K day5	0	0.11502	0.147404	0.318816	0.346734	0.380235	0.471803	0.538805	0.605248	0.647125	0.811837	0.860972	0.910664	1	895.5	465.66
N day0	0	0.164726	0.257439	0.493316	-	0.56188	0.585166	0.670548	0.76326	0.783959	0.871496	0.921949	0.952566	1	1159.5	602.94
N day5	0	-	0.283019	0.487587	0.532274	0.556107	0.572493	0.668322	0.76713	0.790963	0.869414	0.90566	0.940914	1	1007	523.64

See appendix 4(p) for the original line with landmark points as per accuracy tables here.

Accuracy was measured in two ways

1) Straight line distances. This measured x and y coordinates of points on the page and calculated distances between points in straight lines.'

2) Traversing path distances.. This measured line sections by recording actual distances (in pixels) travelled along the line. between points, i.e. actual lengths of line sections as drawn.

Appendix 4(b)

Data derived from appendix 4(a) showing proportions of parts in relation to the whole original line

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	0.174328	0.219104	0.421493	0.469254	0.496716	0.528955	0.58806	0.653731	0.695522	0.797015	0.846567	0.896119	1
Supragla-bella	0.174328	0	0.044776	0.247164	0.294925	0.322388	0.354627	0.413731	0.479403	0.521194	0.622687	0.672239	0.721791	0.825672
Nasion	0.219104	0.044776	0	0.202388	0.250149	0.277612	0.309851	0.368955	0.434627	0.476418	0.57791	0.627463	0.677015	0.780896
Nasal tip	0.421493	0.247164	0.202388	0	0.047761	0.075224	0.107463	0.166567	0.232239	0.27403	0.375522	0.425075	0.474627	0.578507
Nasophiltral junction	0.469254	0.294925	0.250149	0.047761	0	0.027463	0.059701	0.118806	0.184478	0.226269	0.327761	0.377313	0.426866	0.530746
Philtrum	0.496716	0.322388	0.277612	0.075224	0.027463	0	0.032239	0.091343	0.157015	0.198806	0.300299	0.349851	0.399403	0.503284
Top lip	0.528955	0.354627	0.309851	0.107463	0.059701	0.032239	0	0.059104	0.124776	0.166567	0.26806	0.317612	0.367164	0.471045
Oral vertex	0.58806	0.413731	0.368955	0.166567	0.118806	0.091343	0.059104	0	0.065672	0.107463	0.208955	0.258507	0.30806	0.41194
Bottom lip	0.653731	0.479403	0.434627	0.232239	0.184478	0.157015	0.124776	0.065672	0	0.041791	0.143284	0.192836	0.242388	0.346269
Chin depres-sion	0.695522	0.521194	0.476418	0.27403	0.226269	0.198806	0.166567	0.107463	0.041791	0	0.101493	0.151045	0.200597	0.304478
Chin apex	0.797015	0.622687	0.57791	0.375522	0.327761	0.300299	0.26806	0.208955	0.143284	0.101493	0	0.049552	0.099104	0.202985
Chin inflec-tion (jawline)	0.846567	0.672239	0.627463	0.425075	0.377313	0.349851	0.317612	0.258507	0.192836	0.151045	0.049552	0	0.049552	0.153433
Cervical point	0.896119	0.721791	0.677015	0.474627	0.426866	0.399403	0.367164	0.30806	0.242388	0.200597	0.099104	0.049552	0	0.103881
End	1	0.825672	0.780896	0.578507	0.530746	0.503284	0.471045	0.41194	0.346269	0.304478	0.202985	0.153433	0.103881	0

Appendix 4(c)

'Original Line' Straight line distances

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	144.865194	169.934123	332.011321	346.040733	367.361006	391.686695	394.971175	403.710904	437.757566	517.504272	533.520831	547.505156	631.203711
Supragla-bella	144.865194	0	33.897043	187.18916	203.016191	224.562703	249.30615	258.234714	261.027123	295.232224	373.891346	391.850029	408.753551	491.725899
Nasion	169.934123	33.897043	0	164.867444	176.199922	197.456468	221.753161	227.315797	233.782385	267.823943	347.714781	363.733393	378.930799	462.318877
Nasal tip	332.011321	187.18916	164.867444	0	37.799328	53.111935	75.695322	110.446897	84.278759	116.631133	189.489415	212.647343	237.096238	315.96299
Nasophiltral junction	346.040733	203.016191	176.199922	37.799328	0	21.614256	46.610792	73.269439	58.038418	92.254029	171.517566	189.1259	209.113891	290.505602
Philtrum	367.361006	224.562703	197.456468	53.111935	21.614256	0	25.040729	59.233819	36.46447	70.673213	150.399758	167.512091	187.858781	268.986106
Top lip	391.686695	249.30615	221.753161	75.695322	46.610792	25.040729	0	48.077383	12.454621	46.070884	126.845651	142.601646	162.978369	243.946775
Oral vertex	394.971175	258.234714	227.315797	110.446897	73.269439	59.233819	48.077383	0	52.678795	66.373773	141.756816	144.535129	152.784543	236.673356
Bottom lip	403.710904	261.027123	233.782385	84.278759	58.038418	36.46447	12.454621	52.678795	0	34.215617	114.492343	131.162514	153.022361	233.16093
Chin depres-sion	437.757566	295.232224	267.823943	116.631133	92.254029	70.673213	46.070884	66.373773	34.215617	0	81.53822	97.035365	120.829353	199.547674
Chin apex	517.504272	373.891346	347.714781	189.489415	171.517566	150.399758	126.845651	141.756816	114.492343	81.53822	0	39.208688	79.791542	135.45424
Chin inflec-tion (jawline)	533.520831	391.850029	363.733393	212.647343	189.1259	167.512091	142.601646	144.535129	131.162514	97.035365	39.208688	0	40.779373	103.854385
Cervical point	547.505156	408.753551	378.930799	237.096238	209.113891	187.858781	162.978369	152.784543	153.022361	120.829353	79.791542	40.779373	0	83.909258
End	631.203711	491.725899	462.318877	315.96299	290.505602	268.986106	243.946775	236.673356	233.16093	199.547674	135.45424	103.854385	83.909258	0

Appendix 4(d)

Image A day 0 - Distances by traversing path

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	0.092593	0.165165	0.290791	0.352352	0.389389	0.427427	0.540541	0.657157	0.731231	0.817317	0.866366	0.913914	1
Supragla-bella	0.092593	0	0.072573	0.198198	0.25976	0.296797	0.334835	0.447948	0.564565	0.638639	0.724725	0.773774	0.821321	0.907407
Nasion	0.165165	0.072573	0	0.125626	0.187187	0.224224	0.262262	0.375375	0.491992	0.566066	0.652152	0.701201	0.748749	0.834835
Nasal tip	0.290791	0.198198	0.125626	0	0.061562	0.098599	0.136637	0.24975	0.366366	0.44044	0.526527	0.575576	0.623123	0.709209
Nasophiltral junction	0.352352	0.25976	0.187187	0.061562	0	0.037037	0.075075	0.188188	0.304805	0.378879	0.464965	0.514014	0.561562	0.647648
Philtrum	0.389389	0.296797	0.224224	0.098599	0.037037	0	0.038038	0.151151	0.267768	0.341842	0.427928	0.476977	0.524525	0.610611
Top lip	0.427427	0.334835	0.262262	0.136637	0.075075	0.038038	0	0.113113	0.22973	0.303804	0.38989	0.438939	0.486486	0.572573
Oral vertex	0.540541	0.447948	0.375375	0.24975	0.188188	0.151151	0.113113	0	0.116617	0.190691	0.276777	0.325826	0.373373	0.459459
Bottom lip	0.657157	0.564565	0.491992	0.366366	0.304805	0.267768	0.22973	0.116617	0	0.074074	0.16016	0.209209	0.256757	0.342843
Chin depres-sion	0.731231	0.638639	0.566066	0.44044	0.378879	0.341842	0.303804	0.190691	0.074074	0	0.086086	0.135135	0.182683	0.268769
Chin apex	0.817317	0.724725	0.652152	0.526527	0.464965	0.427928	0.38989	0.276777	0.16016	0.086086	0	0.049049	0.096597	0.182683
Chin inflec-tion (jawline)	0.866366	0.773774	0.701201	0.575576	0.514014	0.476977	0.438939	0.325826	0.209209	0.135135	0.049049	0	0.047548	0.133634
Cervical point	0.913914	0.821321	0.748749	0.623123	0.561562	0.524525	0.486486	0.373373	0.256757	0.182683	0.096597	0.047548	0	0.086086
End	1	0.907407	0.834835	0.709209	0.647648	0.610611	0.572573	0.459459	0.342843	0.268769	0.182683	0.133634	0.086086	0

Appendix 4(e)

Image A day 0 Straight Line distances

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	92.401555	158.760624	254.173608	264.259541	300.04343	336.522429	348.777901	362.623869	432.73693	514.026149	529.713414	547.927155	627.671867
Supragla-bella	92.401555	0	70.183402	164.268961	171.978553	207.670169	244.177014	263.663983	270.287952	340.458296	421.63048	437.81122	457.160998	536.486425
Nasion	158.760624	70.183402	0	121.341995	109.745776	145.972267	181.525339	193.509217	207.281796	276.530991	358.905919	371.961353	389.198973	469.071982
Nasal tip	254.173608	164.268961	121.341995	0	59.731462	73.221319	103.739038	182.677035	127.137675	194.393068	269.370979	294.077745	322.468423	396.731563
Nasophiltral junction	264.259541	171.978553	109.745776	59.731462	0	36.251816	72.344412	124.754909	98.400898	168.4844	250.027489	266.202184	287.988658	366.103283
Philtrum	300.04343	207.670169	145.972267	73.221319	36.251816	0	36.59355	115.184511	62.704523	133.002926	214.021427	231.552918	255.350379	332.404091
Top lip	336.522429	244.177014	181.525339	103.739038	72.344412	36.59355	0	108.146286	26.120399	96.409465	177.688319	195.119828	220.034568	296.351318
Oral vertex	348.777901	263.663983	193.509217	182.677035	124.754909	115.184511	108.146286	0	111.402085	142.937057	217.184436	210.318897	212.948342	293.332537
Bottom lip	362.623869	270.287952	207.281796	127.137675	98.400898	62.704523	26.120399	111.402085	0	70.308085	151.708563	169.282788	195.423916	270.90541
Chin depres-sion	432.73693	340.458296	276.530991	194.393068	168.4844	133.002926	96.409465	142.937057	70.308085	0	82.998098	99.747718	130.528578	202.365141
Chin apex	514.026149	421.63048	358.905919	269.370979	250.027489	214.021427	177.688319	217.184436	151.708563	82.998098	0	46.690409	92.176351	138.611672
Chin inflec-tion (jawline)	529.713414	437.81122	371.961353	294.077745	266.202184	231.552918	195.119828	210.318897	169.282788	99.747718	46.690409	0	45.487476	103.056745
Cervical point	547.927155	457.160998	389.198973	322.468423	287.988658	255.350379	220.034568	212.948342	195.423916	130.528578	92.176351	45.487476	0	80.768719
End	627.671867	536.486425	469.071982	396.731563	366.103283	332.404091	296.351318	293.332537	270.90541	202.365141	138.611672	103.056745	80.768719	0

Appendix 4(f)

Image A day 5 Distances by traversing path:

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	0.146866	0.192836	0.393433	0.449552	0.468657	0.49194	0.572537	0.660896	0.687761	0.825075	0.859104	0.900299	1
Supragla-bella	0.146866	0	0.04597	0.246567	0.302687	0.321791	0.345075	0.425672	0.51403	0.540896	0.678209	0.712239	0.753433	0.853134
Nasion	0.192836	0.04597	0	0.200597	0.256716	0.275821	0.299104	0.379701	0.46806	0.494925	0.632239	0.666269	0.707463	0.807164
Nasal tip	0.393433	0.246567	0.200597	0	0.056119	0.075224	0.098507	0.179104	0.267463	0.294328	0.431642	0.465672	0.506866	0.606567
Nasophiltral junction	0.449552	0.302687	0.256716	0.056119	0	0.019104	0.042388	0.122985	0.211343	0.238209	0.375522	0.409552	0.450746	0.550448
Philtrum	0.468657	0.321791	0.275821	0.075224	0.019104	0	0.023284	0.103881	0.192239	0.219104	0.356418	0.390448	0.431642	0.531343
Top lip	0.49194	0.345075	0.299104	0.098507	0.042388	0.023284	0	0.080597	0.168955	0.195821	0.333134	0.367164	0.408358	0.50806
Oral vertex	0.572537	0.425672	0.379701	0.179104	0.122985	0.103881	0.080597	0	0.088358	0.115224	0.252537	0.286567	0.327761	0.427463
Bottom lip	0.660896	0.51403	0.46806	0.267463	0.211343	0.192239	0.168955	0.088358	0	0.026866	0.164179	0.198209	0.239403	0.339104
Chin depres-sion	0.687761	0.540896	0.494925	0.294328	0.238209	0.219104	0.195821	0.115224	0.026866	0	0.137313	0.171343	0.212537	0.312239
Chin apex	0.825075	0.678209	0.632239	0.431642	0.375522	0.356418	0.333134	0.252537	0.164179	0.137313	0	0.03403	0.075224	0.174925
Chin inflec-tion (jawline)	0.859104	0.712239	0.666269	0.465672	0.409552	0.390448	0.367164	0.286567	0.198209	0.171343	0.03403	0	0.041194	0.140896
Cervical point	0.900299	0.753433	0.707463	0.506866	0.450746	0.431642	0.408358	0.327761	0.239403	0.212537	0.075224	0.041194	0	0.099701
End	1	0.853134	0.807164	0.606567	0.550448	0.531343	0.50806	0.427463	0.339104	0.312239	0.174925	0.140896	0.099701	0

Appendix 4(g)

Image A day 5 Straight line distances:

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	122.713254	147.62757	308.728097	332.819576	348.690059	366.511112	363.984354	388.473364	409.700876	521.553437	534.655345	549.633726	629.798546
Supragla-bella	122.713254	0	34.280239	186.032402	211.239794	227.113103	245.320428	249.702255	267.212127	288.784253	400.737221	415.149459	432.051114	511.606343
Nasion	147.62757	34.280239	0	166.025661	185.785842	201.609345	219.149381	218.456902	241.116077	262.188484	373.971539	387.098067	402.669951	482.637101
Nasal tip	308.728097	186.032402	166.025661	0	45.726489	56.747868	74.922662	119.891384	93.419919	115.303307	223.130504	242.099666	265.105878	340.503789
Nasophiltral junction	332.819576	211.239794	185.785842	45.726489	0	15.87934	34.449529	75.350388	56.085175	77.983029	189.70049	205.628853	225.86492	303.47646
Philtrum	348.690059	227.113103	201.609345	56.747868	15.87934	0	19.074222	71.327235	40.316227	62.335299	173.894944	190.128244	210.922717	288.126606
Top lip	366.511112	245.320428	219.149381	74.922662	34.449529	19.074222	0	64.558637	21.96747	43.568735	155.437407	171.191029	191.851278	269.110677
Oral vertex	363.984354	249.702255	218.456902	119.891384	75.350388	71.327235	64.558637	0	71.23102	77.44392	170.81518	176.74698	186.953907	267.407694
Bottom lip	388.473364	267.212127	241.116077	93.419919	56.085175	40.316227	21.96747	71.23102	0	22.174055	133.617627	150.012006	171.787881	248.185669
Chin depres-sion	409.700876	288.784253	262.188484	115.303307	77.983029	62.335299	43.568735	77.44392	22.174055	0	111.958525	127.853901	149.803563	226.011614
Chin apex	521.553437	400.737221	373.971539	223.130504	189.70049	173.894944	155.437407	170.81518	133.617627	111.958525	0	28.212484	61.491561	120.053682
Chin inflec-tion (jawline)	534.655345	415.149459	387.098067	242.099666	205.628853	190.128244	171.191029	176.74698	150.012006	127.853901	28.212484	0	33.314166	98.405294
Cervical point	549.633726	432.051114	402.669951	265.105878	225.86492	210.922717	191.851278	186.953907	171.787881	149.803563	61.491561	33.314166	0	80.454548
End	629.798546	511.606343	482.637101	340.503789	303.47646	288.126606	269.110677	267.407694	248.185669	226.011614	120.053682	98.405294	80.454548	0

Appendix 4(h)

Image K day 0 Distances by traversing path:

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	0.131671	0.179052	0.343641	-	0.419451	0.446883	0.546135	0.649377	0.704239	0.802993	0.850873	0.899751	1
Supragla-bella	0.131671	0	0.047382	0.21197	-	0.287781	0.315212	0.414464	0.517706	0.572569	0.671322	0.719202	0.76808	0.868329
Nasion	0.179052	0.047382	0	0.164589	-	0.240399	0.26783	0.367082	0.470324	0.525187	0.62394	0.67182	0.720698	0.820948
Nasal tip	0.343641	0.21197	0.164589	0	-	0.07581	0.103242	0.202494	0.305736	0.360599	0.459352	0.507232	0.55611	0.656359
Nasophiltral junction	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Philtrum	0.419451	0.287781	0.240399	0.07581	-	0	0.027431	0.126683	0.229925	0.284788	0.383541	0.431421	0.480299	0.580549
Top lip	0.446883	0.315212	0.26783	0.103242	-	0.027431	0	0.099252	0.202494	0.257357	0.35611	0.40399	0.452868	0.553117
Oral vertex	0.546135	0.414464	0.367082	0.202494	-	0.126683	0.099252	0	0.103242	0.158105	0.256858	0.304738	0.353616	0.453865
Bottom lip	0.649377	0.517706	0.470324	0.305736	-	0.229925	0.202494	0.103242	0	0.054863	0.153616	0.201496	0.250374	0.350623
Chin depres-sion	0.704239	0.572569	0.525187	0.360599	-	0.284788	0.257357	0.158105	0.054863	0	0.098753	0.146633	0.195511	0.295761
Chin apex	0.802993	0.671322	0.62394	0.459352	-	0.383541	0.35611	0.256858	0.153616	0.098753	0	0.04788	0.096758	0.197007
Chin inflec-tion (jawline)	0.850873	0.719202	0.67182	0.507232	-	0.431421	0.40399	0.304738	0.201496	0.146633	0.04788	0	0.048878	0.149127
Cervical point	0.899751	0.76808	0.720698	0.55611	-	0.480299	0.452868	0.353616	0.250374	0.195511	0.096758	0.048878	0	0.100249
End	1	0.868329	0.820948	0.656359	-	0.580549	0.553117	0.453865	0.350623	0.295761	0.197007	0.149127	0.100249	0

Appendix 4(i)

Image K day 0 Straight line distances:

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	121.085725	141.605597	292.593865	-	317.005799	344.086249	338.946268	372.60539	420.130905	499.160947	518.430834	536.269716	631.247732
Supragla-bella	121.085725	0	29.16181	171.674834	-	197.075719	224.299866	231.856229	253.174039	300.464042	378.147732	398.278091	418.050071	513.480295
Nasion	141.605597	29.16181	0	156.288686	-	175.714387	202.67525	203.957367	231.056389	278.615146	359.176103	377.06485	394.773116	489.896417
Nasal tip	292.593865	171.674834	156.288686	0	-	51.495122	71.910178	143.407671	98.907878	140.685934	208.306532	233.15865	260.391999	355.382988
Nasophiltral junction	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Philtrum	317.005799	197.075719	175.714387	51.495122	-	0	27.255919	95.759307	56.386505	103.398003	184.824853	201.425035	221.932269	317.558307
Top lip	344.086249	224.299866	202.67525	71.910178	-	27.255919	0	94.090721	29.235621	76.164263	159.308057	174.389602	194.785833	290.413225
Oral vertex	338.946268	231.856229	203.957367	143.407671	-	95.759307	94.090721	0	97.436764	128.509469	218.731555	215.469189	215.254759	304.273227
Bottom lip	372.60539	253.174039	231.056389	98.907878	-	56.386505	29.235621	97.436764	0	47.60035	134.554766	146.319905	165.562138	261.190082
Chin depres-sion	420.130905	300.464042	278.615146	140.685934	-	103.398003	76.164263	128.509469	47.60035	0	91.164726	98.769089	119.886649	215.276278
Chin apex	499.160947	378.147732	359.176103	208.306532	-	184.824853	159.308057	218.731555	134.554766	91.164726	0	44.410273	91.554962	166.584489
Chin inflec-tion (jawline)	518.430834	398.278091	377.06485	233.15865	-	201.425035	174.389602	215.469189	146.319905	98.769089	44.410273	0	47.381495	127.10791
Cervical point	536.269716	418.050071	394.773116	260.391999	-	221.932269	194.785833	215.254759	165.562138	119.886649	91.554962	47.381495	0	95.62795
End	631.247732	513.480295	489.896417	355.382988	-	317.558307	290.413225	304.273227	261.190082	215.276278	166.584489	127.10791	95.62795	0

Appendix 4(j)

Image K day 5 Distances by traversing path:

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	0.11502	0.147404	0.318816	0.346734	0.380235	0.471803	0.538805	0.605248	0.647125	0.811837	0.860972	0.910664	1
Supragla-bella	0.11502	0	0.032384	0.203797	0.231714	0.265215	0.356784	0.423786	0.490229	0.532105	0.696817	0.745952	0.795645	0.88498
Nasion	0.147404	0.032384	0	0.171413	0.19933	0.232831	0.3244	0.391401	0.457845	0.499721	0.664433	0.713568	0.763261	0.852596
Nasal tip	0.318816	0.203797	0.171413	0	0.027917	0.061418	0.152987	0.219989	0.286432	0.328308	0.493021	0.542155	0.591848	0.681184
Nasophiltral junction	0.346734	0.231714	0.19933	0.027917	0	0.033501	0.12507	0.192071	0.258515	0.300391	0.465103	0.514238	0.563931	0.653266
Philtrum	0.380235	0.265215	0.232831	0.061418	0.033501	0	0.091569	0.158571	0.225014	0.26689	0.431602	0.480737	0.53043	0.619765
Top lip	0.471803	0.356784	0.3244	0.152987	0.12507	0.091569	0	0.067002	0.133445	0.175321	0.340034	0.389168	0.438861	0.528197
Oral vertex	0.538805	0.423786	0.391401	0.219989	0.192071	0.158571	0.067002	0	0.066443	0.108319	0.273032	0.322166	0.371859	0.461195
Bottom lip	0.605248	0.490229	0.457845	0.286432	0.258515	0.225014	0.133445	0.066443	0	0.041876	0.206588	0.255723	0.305416	0.394752
Chin depres-sion	0.647125	0.532105	0.499721	0.328308	0.300391	0.26689	0.175321	0.108319	0.041876	0	0.164712	0.213847	0.26354	0.352875
Chin apex	0.811837	0.696817	0.664433	0.493021	0.465103	0.431602	0.340034	0.273032	0.206588	0.164712	0	0.049135	0.098827	0.188163
Chin inflec-tion (jawline)	0.860972	0.745952	0.713568	0.542155	0.514238	0.480737	0.389168	0.322166	0.255723	0.213847	0.049135	0	0.049693	0.139028
Cervical point	0.910664	0.795645	0.763261	0.591848	0.563931	0.53043	0.438861	0.371859	0.305416	0.26354	0.098827	0.049693	0	0.089336
End	1	0.88498	0.852596	0.681184	0.653266	0.619765	0.528197	0.461195	0.394752	0.352875	0.188163	0.139028	0.089336	0

Appendix 4(k)

Image K day 5 Straight line distances:

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	102.013169	116.052323	263.226412	264.69203	291.830658	361.011066	362.344729	375.160793	411.860571	540.117075	539.321832	554.813937	633.529709
Supragla-bella	102.013169	0	25.673944	161.989395	165.484868	193.512473	264.622421	273.748344	279.285582	315.665467	440.286766	441.723873	459.890963	538.943433
Nasion	116.052323	25.673944	0	148.232004	148.657029	175.819518	245.587986	251.381882	259.961469	296.574715	424.073796	423.616224	440.233833	519.170855
Nasal tip	263.226412	161.989395	148.232004	0	23.330195	44.245016	113.476489	145.634246	128.639341	162.351383	278.966812	283.384719	305.957234	384.684937
Nasophiltral junction	264.69203	165.484868	148.657029	23.330195	0	28.702533	101.04225	126.228422	116.1411	151.615174	275.425968	276.347888	296.115482	375.155985
Philtrum	291.830658	193.512473	175.819518	44.245016	28.702533	0	72.342297	101.58923	87.4523	122.948093	248.605953	248.217372	267.462278	346.515571
Top lip	361.011066	264.622421	245.587986	113.476489	101.04225	72.342297	0	57.888935	15.191902	51.047278	184.144675	178.475116	195.417758	274.497892
Oral vertex	362.344729	273.748344	251.381882	145.634246	126.228422	101.58923	57.888935	0	54.987286	75.754051	210.87716	193.557406	198.049171	274.693226
Bottom lip	375.160793	279.285582	259.961469	128.639341	116.1411	87.4523	15.191902	54.987286	0	36.723877	172.47439	164.805865	180.624185	259.696017
Chin depres-sion	411.860571	315.665467	296.574715	162.351383	151.615174	122.948093	51.047278	75.754051	36.723877	0	138.090802	128.191738	144.51899	223.584253
Chin apex	540.117075	440.286766	424.073796	278.966812	275.425968	248.605953	184.144675	210.87716	172.47439	138.090802	0	42.940761	84.926659	134.550976
Chin inflec-tion (jawline)	539.321832	441.723873	423.616224	283.384719	276.347888	248.217372	178.475116	193.557406	164.805865	128.191738	42.940761	0	43.017621	106.820608
Cervical point	554.813937	459.890963	440.233833	305.957234	296.115482	267.462278	195.417758	198.049171	180.624185	144.51899	84.926659	43.017621	0	79.080162
End	633.529709	538.943433	519.170855	384.684937	375.155985	346.515571	274.497892	274.693226	259.696017	223.584253	134.550976	106.820608	79.080162	0

Appendix 4(l)

Image N day 0 Distances by traversing path:

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	0.164726	0.257439	0.493316	-	0.56188	0.585166	0.670548	0.76326	0.783959	0.871496	0.921949	0.952566	1
Supragla-bella	0.164726	0	0.092712	0.32859	-	0.397154	0.42044	0.505821	0.598534	0.619232	0.70677	0.757223	0.78784	0.835274
Nasion	0.257439	0.092712	0	0.235878	-	0.304442	0.327727	0.413109	0.505821	0.52652	0.614058	0.664511	0.695127	0.742561
Nasal tip	0.493316	0.32859	0.235878	0	-	0.068564	0.09185	0.177232	0.269944	0.290643	0.37818	0.428633	0.45925	0.506684
Nasophiltral junction	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Philtrum	0.56188	0.397154	0.304442	0.068564	-	0	0.023286	0.108668	0.20138	0.222078	0.309616	0.360069	0.390686	0.43812
Top lip	0.585166	0.42044	0.327727	0.09185	-	0.023286	0	0.085382	0.178094	0.198793	0.28633	0.336783	0.3674	0.414834
Oral vertex	0.670548	0.505821	0.413109	0.177232	-	0.108668	0.085382	0	0.092712	0.113411	0.200949	0.251401	0.282018	0.329452
Bottom lip	0.76326	0.598534	0.505821	0.269944	-	0.20138	0.178094	0.092712	0	0.020699	0.108236	0.158689	0.189306	0.23674
Chin depres-sion	0.783959	0.619232	0.52652	0.290643	-	0.222078	0.198793	0.113411	0.020699	0	0.087538	0.137991	0.168607	0.216041
Chin apex	0.871496	0.70677	0.614058	0.37818	-	0.309616	0.28633	0.200949	0.108236	0.087538	0	0.050453	0.081069	0.128504
Chin inflec-tion (jawline)	0.921949	0.757223	0.664511	0.428633	-	0.360069	0.336783	0.251401	0.158689	0.137991	0.050453	0	0.030617	0.078051
Cervical point	0.952566	0.78784	0.695127	0.45925	-	0.390686	0.3674	0.282018	0.189306	0.168607	0.081069	0.030617	0	0.047434
End	1	0.835274	0.742561	0.506684	-	0.43812	0.414834	0.329452	0.23674	0.216041	0.128504	0.078051	0.047434	0

Appendix 4(m)

Image N day 0 Straight line distances:

	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	188.943656	219.810871	478.07007	-	462.353613	483.924002	441.689583	505.752091	524.021746	619.278749	624.938832	617.345675	663.524293
Supragla-bella	188.943656	0	80.922073	308.367507	-	303.417946	327.59861	314.903939	349.881679	370.91655	458.237733	474.249384	474.298955	523.423856
Nasion	219.810871	80.922073	0	258.281519	-	243.870641	266.389443	239.816583	288.540084	307.993579	401.012303	410.617498	406.888806	455.040995
Nasal tip	478.07007	308.367507	258.281519	0	-	45.219693	56.582257	143.65263	68.013023	88.981188	152.484112	180.18735	192.977309	241.473142
Nasophiltral junction	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Philtrum	462.353613	303.417946	243.870641	45.219693	-	0	25.033011	98.433806	46.797365	68.8408	157.146805	171.412362	176.011285	225.756096
Top lip	483.924002	327.59861	266.389443	56.582257	-	25.033011	0	95.905657	22.313183	43.863416	135.495106	146.79719	150.99292	200.732742
Oral vertex	441.689583	314.903939	239.816583	143.65263	-	98.433806	95.905657	0	105.341713	109.81854	205.43236	192.506293	178.166909	222.357026
Bottom lip	505.752091	349.881679	288.540084	68.013023	-	46.797365	22.313183	105.341713	0	22.635178	114.111447	124.63566	130.189505	179.807887
Chin depres-sion	524.021746	370.91655	307.993579	88.981188	-	68.8408	43.863416	109.81854	22.635178	0	98.882319	103.341297	107.576812	157.226986
Chin apex	619.278749	458.237733	401.012303	152.484112	-	157.146805	135.495106	205.43236	114.111447	98.882319	0	53.450618	86.940529	117.279119
Chin inflec-tion (jawline)	624.938832	474.249384	410.617498	180.18735	-	171.412362	146.79719	192.506293	124.63566	103.341297	53.450618	0	35.130233	66.52371
Cervical point	617.345675	474.298955	406.888806	192.977309	-	176.011285	150.99292	178.166909	130.189505	107.576812	86.940529	35.130233	0	49.756851
End	663.524293	523.423856	455.040995	241.473142	-	225.756096	200.732742	222.357026	179.807887	157.226986	117.279119	66.52371	49.756851	0

Appendix 4(n)

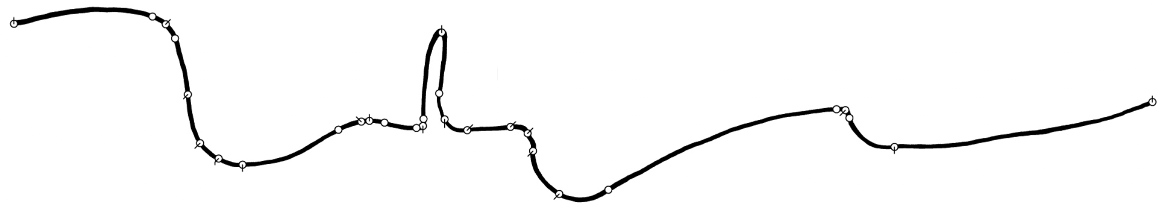
Image N day 5 Distances by traversing path:

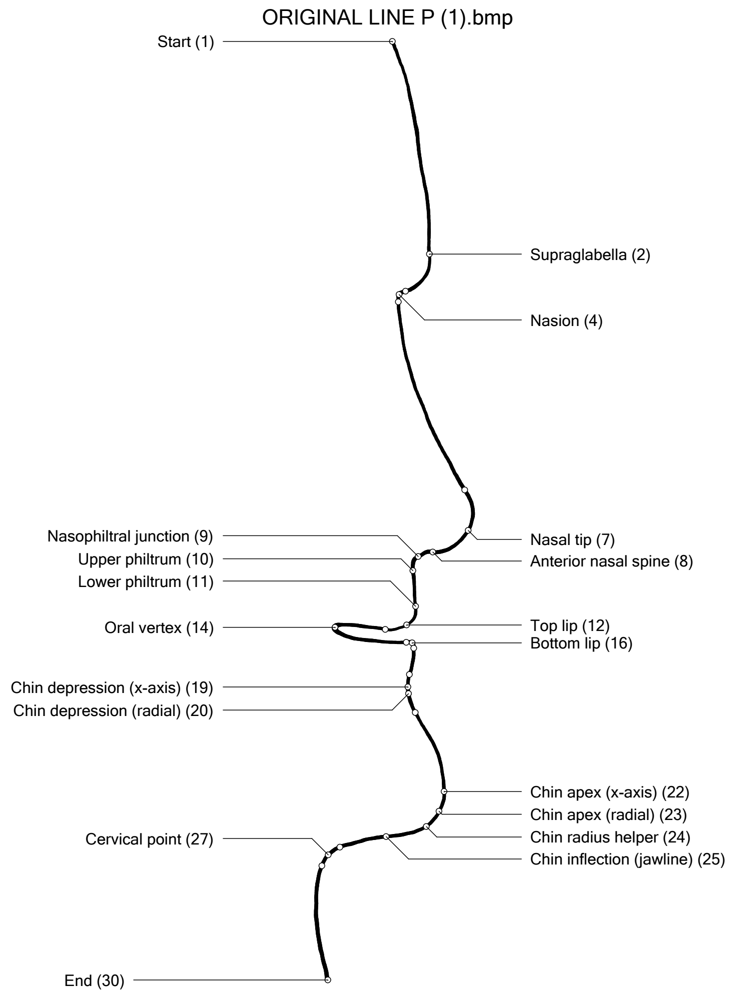
	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	-	0.283019	0.487587	0.532274	0.556107	0.572493	0.668322	0.76713	0.790963	0.869414	0.90566	0.940914	1
Supragla-bella	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nasion	0.283019	-	0	0.204568	0.249255	0.273088	0.289474	0.385303	0.484111	0.507944	0.586395	0.622642	0.657895	0.716981
Nasal tip	0.487587	-	0.204568	0	0.044687	0.06852	0.084906	0.180735	0.279543	0.303376	0.381827	0.418073	0.453327	0.512413
Nasophiltral junction	0.532274	-	0.249255	0.044687	0	0.023833	0.040218	0.136048	0.234856	0.258689	0.33714	0.373386	0.40864	0.467726
Philtrum	0.556107	-	0.273088	0.06852	0.023833	0	0.016385	0.112214	0.211023	0.234856	0.313307	0.349553	0.384806	0.443893
Top lip	0.572493	-	0.289474	0.084906	0.040218	0.016385	0	0.095829	0.194638	0.218471	0.296922	0.333168	0.368421	0.427507
Oral vertex	0.668322	-	0.385303	0.180735	0.136048	0.112214	0.095829	0	0.098808	0.122642	0.201092	0.237339	0.272592	0.331678
Bottom lip	0.76713	-	0.484111	0.279543	0.234856	0.211023	0.194638	0.098808	0	0.023833	0.102284	0.13853	0.173784	0.23287
Chin depres-sion	0.790963	-	0.507944	0.303376	0.258689	0.234856	0.218471	0.122642	0.023833	0	0.078451	0.114697	0.14995	0.209037
Chin apex	0.869414	-	0.586395	0.381827	0.33714	0.313307	0.296922	0.201092	0.102284	0.078451	0	0.036246	0.0715	0.130586
Chin inflec-tion (jawline)	0.90566	-	0.622642	0.418073	0.373386	0.349553	0.333168	0.237339	0.13853	0.114697	0.036246	0	0.035253	0.09434
Cervical point	0.940914	-	0.657895	0.453327	0.40864	0.384806	0.368421	0.272592	0.173784	0.14995	0.0715	0.035253	0	0.059086
End	1	-	0.716981	0.512413	0.467726	0.443893	0.427507	0.331678	0.23287	0.209037	0.130586	0.09434	0.059086	0

Appendix 4(o)

Image N day 5 Straight line distances:

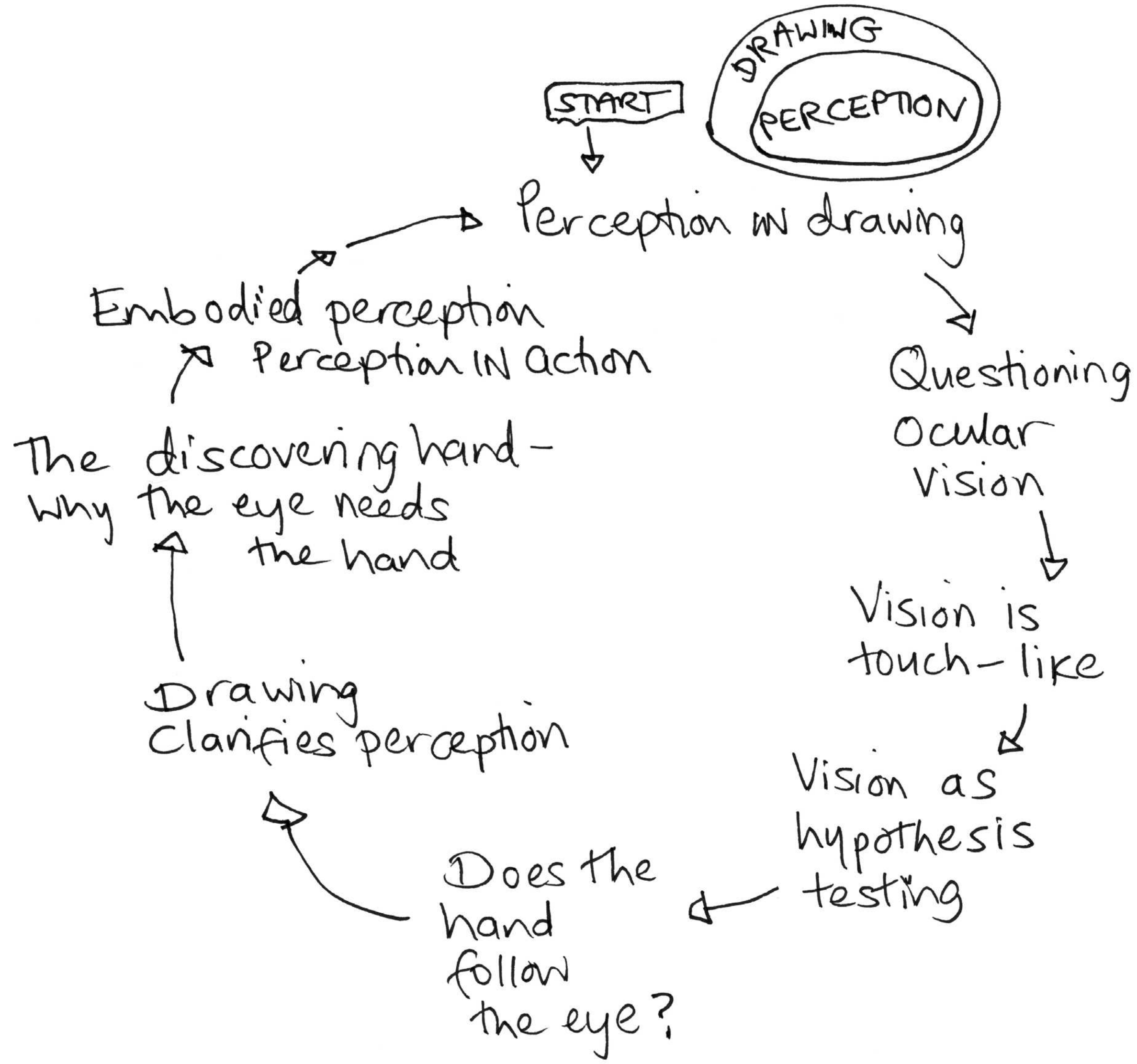
	Start	Supragla-bella	Nasion	Nasal tip	Nasophiltral junction	Philtrum	Top lip	Oral vertex	Bottom lip	Chin depres-sion	Chin apex	Chin inflec-tion (jawline)	Cervical point	End
Start	0	-	241.328667	438.6867	440.310345	459.510045	474.803049	463.840329	491.671473	513.432464	585.376556	595.144561	590.087527	643.133664
Supragla-bella	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nasion	241.328667	-	0	201.751031	199.348568	218.211973	233.474503	232.060682	250.356614	272.10398	344.233196	353.900427	349.98164	403.73107
Nasal tip	438.6867	-	201.751031	0	40.316646	56.815241	68.676056	148.558117	82.55181	96.794251	154.98082	174.009353	184.108045	237.70612
Nasophiltral junction	440.310345	-	199.348568	40.316646	0	22.507895	38.294699	108.244496	55.415427	75.319181	145.110223	157.606205	160.747364	215.528713
Philtrum	459.510045	-	218.211973	56.815241	22.507895	0	16.027715	96.050068	33.355233	54.22974	126.254724	136.6237	138.457432	193.274108
Top lip	474.803049	-	233.474503	68.676056	38.294699	16.027715	0	93.386939	17.342644	38.637486	111.650511	120.863683	122.483212	177.28721
Oral vertex	463.840329	-	232.060682	148.558117	108.244496	96.050068	93.386939	0	94.598518	107.753783	169.521876	160.780151	140.923604	186.984584
Bottom lip	491.671473	-	250.356614	82.55181	55.415427	33.355233	17.342644	94.598518	0	22.022686	95.860698	103.703628	105.358736	160.11887
Chin depres-sion	513.432464	-	272.10398	96.794251	75.319181	54.22974	38.637486	107.753783	22.022686	0	73.91709	82.420944	87.475521	141.649016
Chin apex	585.376556	-	344.233196	154.98082	145.110223	126.254724	111.650511	169.521876	95.860698	73.91709	0	31.340434	63.341284	98.470619
Chin inflec-tion (jawline)	595.144561	-	353.900427	174.009353	157.606205	136.6237	120.863683	160.780151	103.703628	82.420944	31.340434	0	34.190747	68.758765
Cervical point	590.087527	-	349.98164	184.108045	160.747364	138.457432	122.483212	140.923604	105.358736	87.475521	63.341284	34.190747	0	54.83428
End	643.133664	-	403.73107	237.70612	215.528713	193.274108	177.28721	186.984584	160.11887	141.649016	98.470619	68.758765	54.83428	0





ORIGINAL LINE P (1).bmp
Start (1)
Supraglabella (2)
Nasion (4)
Nasophiltral junction (9)
Upper philtrum (10)
Lower philtrum (11)
Nasal tip (7)
Anterior nasal spine (8)
Oral vertex (14)
Top lip (12)
Bottom lip (16)
Chin depression (x-axis) (19)
Chin depression (radial) (20)
Chin apex (x-axis) (22)
Chin apex (radial) (23)
Chin radius helper (24)
Cervical point (27)
Chin inflection (jawline) (25)
End (30)

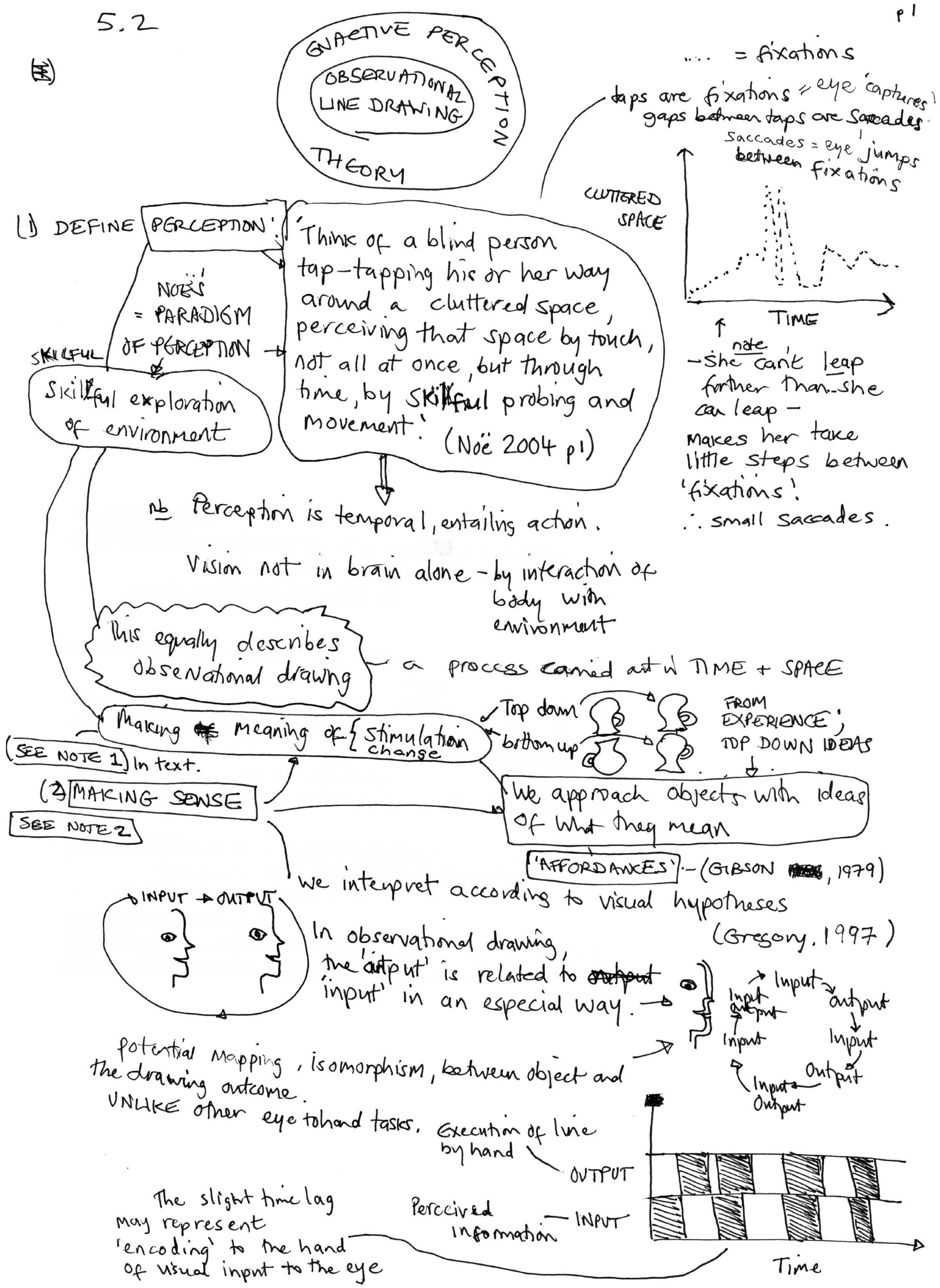
Appendix 5(c)


DRAWING
PERCEPTION
START
Perception IN drawing
Questioning Ocular Vision
Vision is touch-like
Vision as hypothesis testing
Does the hand follow the eye?
Drawing Clarifies perception
The discovering hand - why the eye needs the hand
Embodied perception
Perception IN action

Notes to accompany annotated drawings

Note 1: Observational drawing is here scrutinised using this paradigm of perception, as a process carried out in time and space, by the body. Perception is an interpretation, a making of meaning of stimulation, i.e. of change. The word 'sense' is confusing, as it is generally used to refer to an initial stimulation e.g. activation of retinal cells, and is often assumed to contain no meaning (sense) at this stage. In many ways it would seem more logical to use the word sense for what we commonly refer to as perception – the stage of interpretation of and meaning-giving to sensory stimuli. However perhaps there is some reason to the rhyme: many scientists (and philosophers) now believe that there is no moment of innocence, of pure input to the senses, of meaningless impressions. Top down and bottom up information merge in time and space, so that meaning is brought to the experience along with primary sensory input, so that sense and perception cannot be separated.

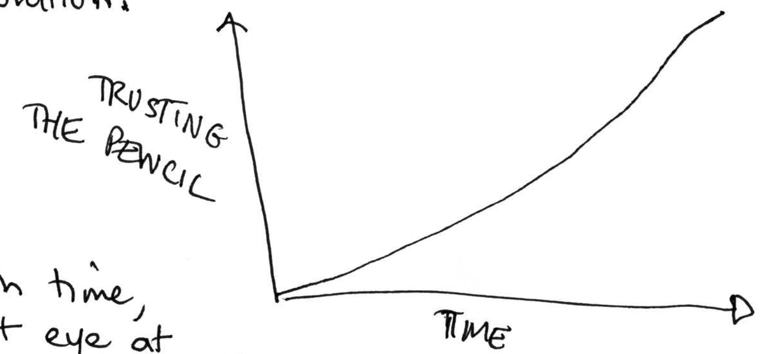
Note 2: In normal life what we experience makes sense – it is already a meaningful interpretation of movements. As Gibson explained it, objects and situations have 'affordances' (Gibson 1979).

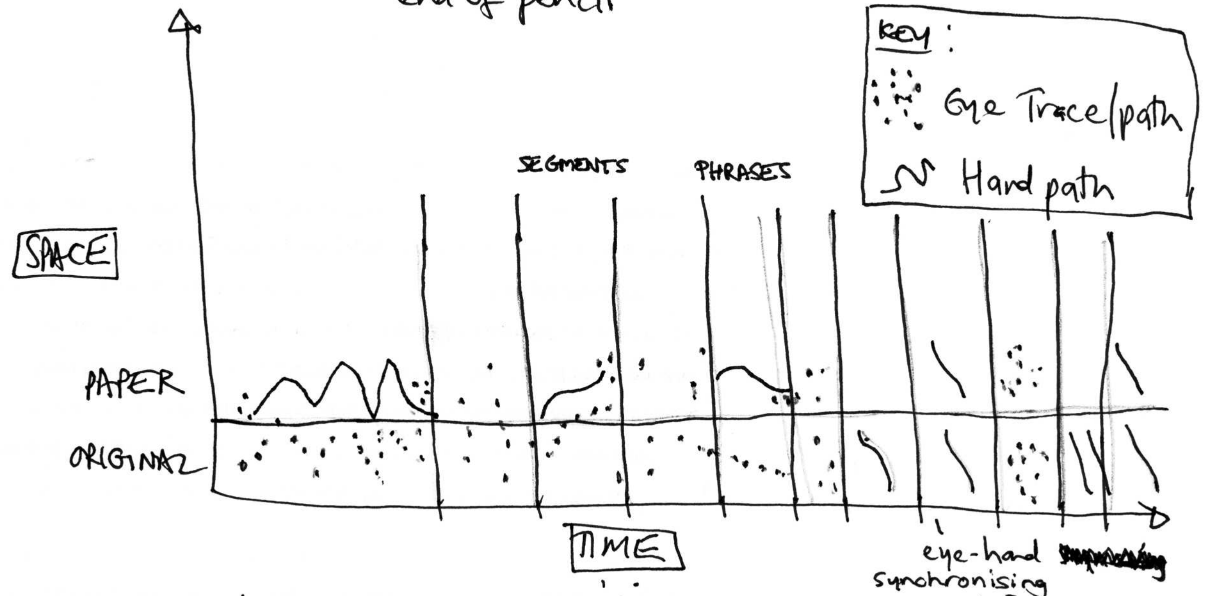


So, because obs. drawing is different, a perception to action paradigm is inadequate for exploration.

(Riley 2009 p20-21)

with time,
- Come to trust eye at end of pencil





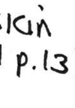
Argument:
- Drawing is a particular way of perceiving space and time, using and coordinating eye and hand in extra-ordinary way.

3) Perception in drawing

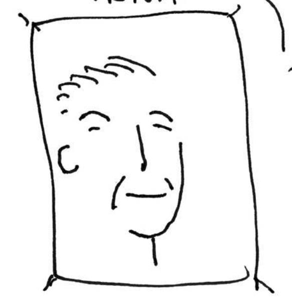
'see keenly' – Ruskin 1971 p.13

? how do we come to this 'keeness of vision'?

For I am nearly convinced, that, when once we see keenly enough, there is very little difficulty in drawing what we see... (Ruskin 1971 p.13)



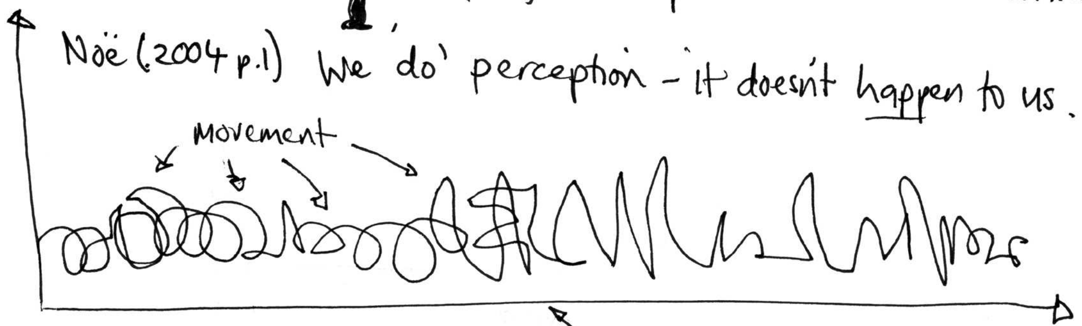
Selective + dedicated vision for drawing.



– perceives a face as series of simple lines

– Tchalenko

Noë (2004 p.1) We 'do' perception – it doesn't happen to us.



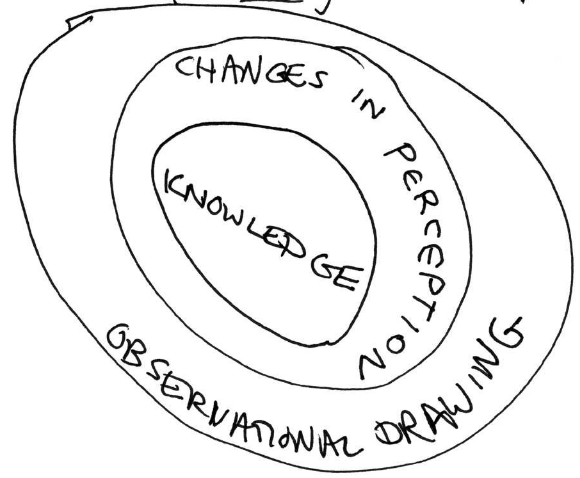
– gaze path – fixations numbered.

perceiver didn't look at the mouth, chin or neck. (see Yarbus 1967)

Perceivers actively control what they perceive, by moving.

Nicolaïdes:

'... increased knowledge with which you look at life around you' (2008 p2)



Knowledge TO Drawing?

Drawing TO knowledge?

Knowledge

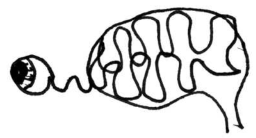
Drawing

Note 3: As we have seen, the dominant paradigm in both science and pedagogy is that the hand is a motor agent, following the perceptive eye, so the eye is thought to do all the work of seeing. In his PhD thesis Howard Riley (2009) explains the philosophical project, stemming back to the Renaissance, that aimed to raise drawing from a handcraft to a fine art. Ocular vision was considered a higher sense, more closely connected with thought and intelligence, so by emphasising the role of the eye in drawing, drawings' status was elevated. In practice, Alberti (1435/1991) proposed that drawers concentrate on how they look at things. In modern times Betty Edwards epitomises the view that drawing accuracy depends on looking. This view was and is held many artists and drawing teachers, over centuries.

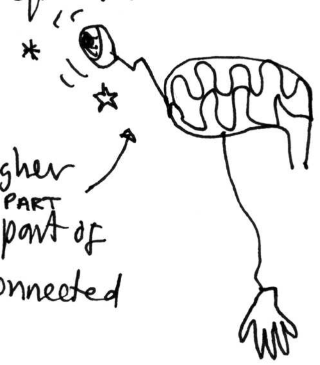
Note 4: The eye is finely tuned to sense movement, and to give us an egocentric view so that we can protect ourselves – e.g. to measure distances between tigers, buses and ourselves. The eye is not designed for drawing. The eye is fast, it swiftly captures essential information fit for purpose – commonly for survival. It identifies movement, depth, or recognises faces in one glance.

4) Is the eye up to the task?

'...it takes a leap of imagination to appreciate that the eyes set extremely difficult problems for the brain to solve for seeing to be possible' (GREGORY 1997 p.1)



In case of drawing the problems are HUGE. Drawing asks particular and detailed questions



The eye has higher status. Eye is PART of brain, closely connected with thought.

Helen Keller thinks that people need hands in order to see:

SEE NOTE 3, HISTORICAL REASONS WHY DRAWING WAS SEEN AS OCULAR-BASED

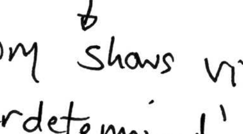
'...When they look at things, they put their hands in their pockets' (Keller 2010 p.42)

She suggests this is a reason why their 'knowledge is often so vague, inaccurate and useless'

looking for drawing

versus everyday vision,

Vision quickly gives us knowledge of danger.

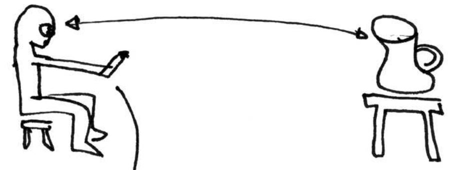


See NOTE 4

Gregory shows vision is 'underdetermined' and 'SKETCHY' (1997 p.2)

4) continued. P.5

'Looking for drawing' uses eye in diametrically opposed way;



Slow grasp, close detail.

The hand is the secret teacher

The hand is more naturally suited for (this) purpose

fine motor control

temporal grasp of detail to build up whole

.. to see the whole

* Drawing requires an especial way of behaving.

Nicolaides:
Like climbing a mountain slowly, versus taking a plane. (2008 p.1)

Note 5: As outlined in Chapter 2 Richard Gregory argues that vision is a research process involving trial and error hypothesis testing. The idea of the eye behaving like the hand in terms of touch, moving over an object, leads to the consideration of whether spatial information is encoded in the scan path of the eyes, as distinct from the retinal display. The implication is that the movements and path of the eyes hold the visual information, in which case drawing relies on a temporal sequence of fixations rather than some sort of mental map of coordinates. Pyschologists Check Noton and Stark (1971) suggested that the scan path itself contained visual memory, that was recalled when the scan path was replayed. However there is little supporting scientific evidence for this (see Land 2008).

Note 6: As well as acknowledging that vision is touch-like, drawing can be a metaphorical probing and touching, a feeling of our way towards understanding and discovery. It is a process of improvisation. Nicolaïdes' metaphor for the slowness of the process, walking versus taking an airplane, refers to the detail focus needed for drawing. The eye is the plane. Observational drawing needs slowness – it is the only way to take in detail.

Note 7 : Lucy Lyons' talks of vision as touch-like, and as 'almost seeing'.

But do you know I think I don't necessarily look but I touch the surface, I feel it, I feel my way round it, and I think especially because object wise, I er work with objects that can't be touched, I 've always felt that the pencil is the only way I could touch it, but then on the other end of the pencil is me and the pencil tip is touching the paper, so I'm sort of seeing it through the touch – if that makes sense.' (Lyons 2013 15mins)

She went on to say 'So it sort of reaches out to me and I have to reach into it, and as that happens..so the tip of my pencil almost sees, through touching on the surface.' (Lyons 2013 16mins 24s)

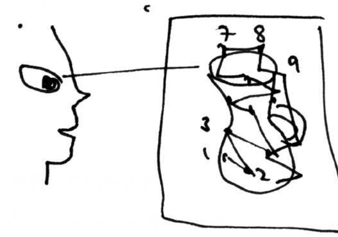
5) Vision is touch-like

IN EVOLUTION, VISION IS YOUNGER THAN TOUCH - AN ADD-ON. IT IS BUILT ON TOUCH.

GREGORY

Vision is touch at a distance

We use vision when things are out of reach



Looking for drawing - like blind people touching, a piecemeal process of identifying objects - temporal capture of details.

Segmentation

to be integrated into a whole.

TCHALENKO

- -. Simple line sections... copied one at a time

(2009a p.791)

* Drawing = Challenge for vision.

~~Drawing~~ the eye has to learn a new way of behaving, to collect detail.

SEE NOTE 5 - How eye scan paths might be encoded.

SEE NOTE 6 - Drawing as improvisation.

LYONS

... I don't necessarily look but I touch the surface, I feel it, I feel my way round it, ..

(LYONS 2013) INTERVIEW

because she works with objects that cannot be touched.

LYONS

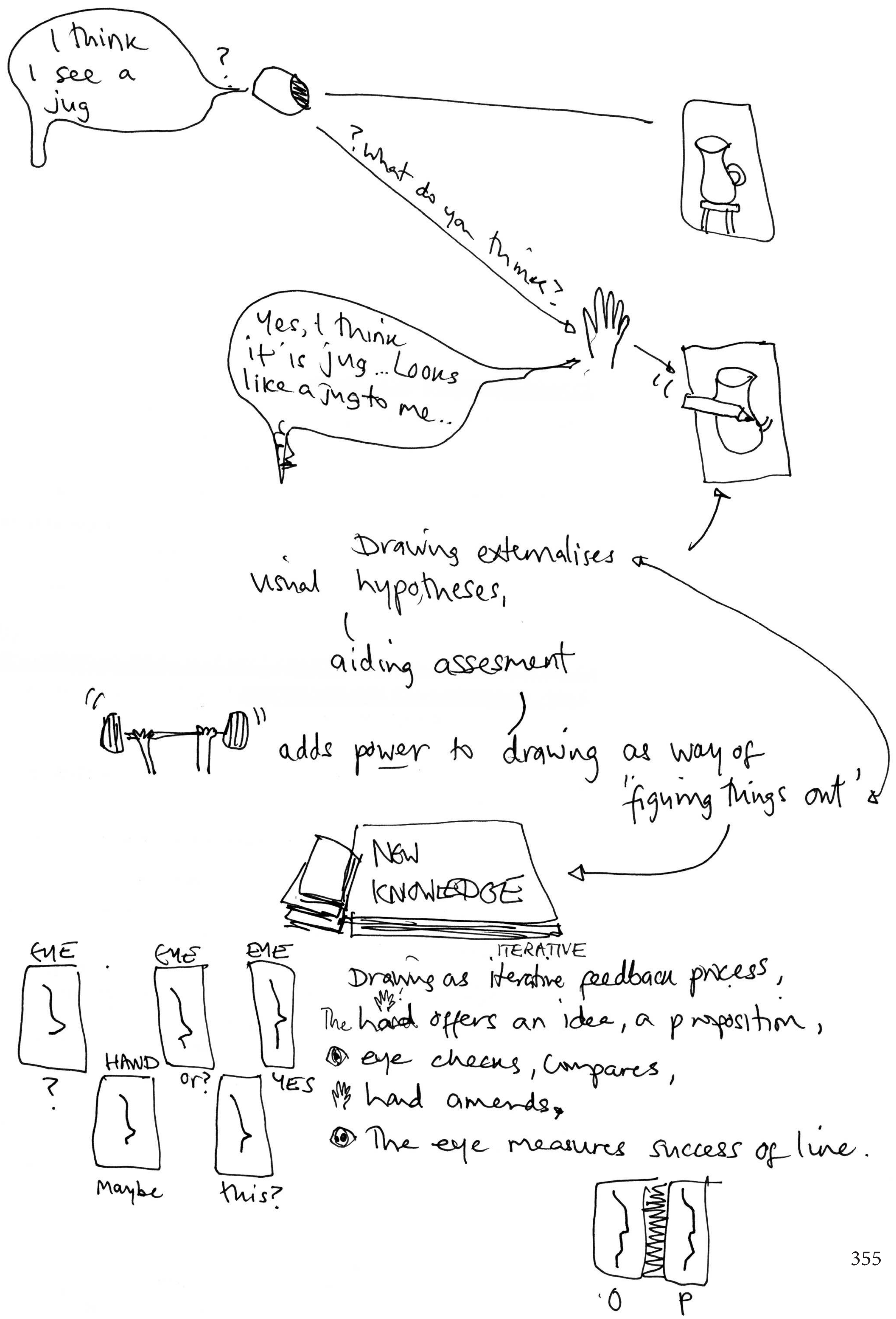
... I've always felt that the pencil is the only way I could touch it, ..

..I'm sort of seeing it through the touch - if that makes sense.

SEE NOTE 7 FOR FULL QUOTE

p. 7

6) Vision as hypothesis testing



Note 8: In Eye and Brain (1997) Gregory outlines the physiology of the eye and relates it to general functioning of the eye, and in the 'Artful Eye' (1995) he distinguishes between 'sight-for-survival' and adapted sight for 'seeing and creating beauty' (1995 p.v). He believes that the eye conducts research, testing hypotheses about what it sees against expectation, based on knowledge and experience. Gregory's 'artful eye' looks at things in an especial way, based on task specific knowledge of the structure of appearance and procedural knowledge of how to make art; the existence of this 'adapted sight' is central to Gregory's thesis. His findings relate to the role of movement and touch in this clarification of vision. Nicolaïdes' perspective from the studio closely connects with Gregory's theory about the role of touch in vision. Across disciplines, Gregory and Gombrich agreed on many aspects of the drawing process. Gregory's view proposed that vision itself consists of perceptual hypotheses and the asking of questions.

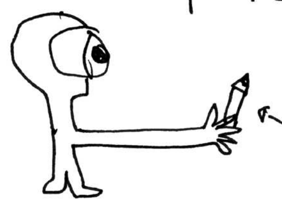
Drawing offers a particular way to test these visual hypotheses, using the hand to manifest the questions and to offer possible answers. The action of the hand may provide answers to perceptual questions and ambiguities. In this way perception is transformed, and the drawer develops a partnership between the eye and hand. Gregory makes an important contribution, continuing Gombrich's line of study of top down knowledge, and offering a view of extra-ordinary perception for drawing, based on Gombrich's schema theory. He supports the 'active vision' view.

P.8

6) continued.

See Note 8: Gregory 1997, 1995

'Adapted sight' - adapted by experience

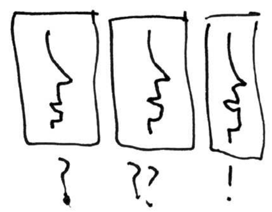


Gregory looks at the role of the hand to disambiguate vision.

disambiguate = (to make clear)

* This progresses the argument - gives perceptual role to hand.

The hand manifests visual questions -



offers possible answers

transformed by perception

Eye Hand partnership

Role for touch and gesture in visual perception.

* Research model of vision AND drawing.

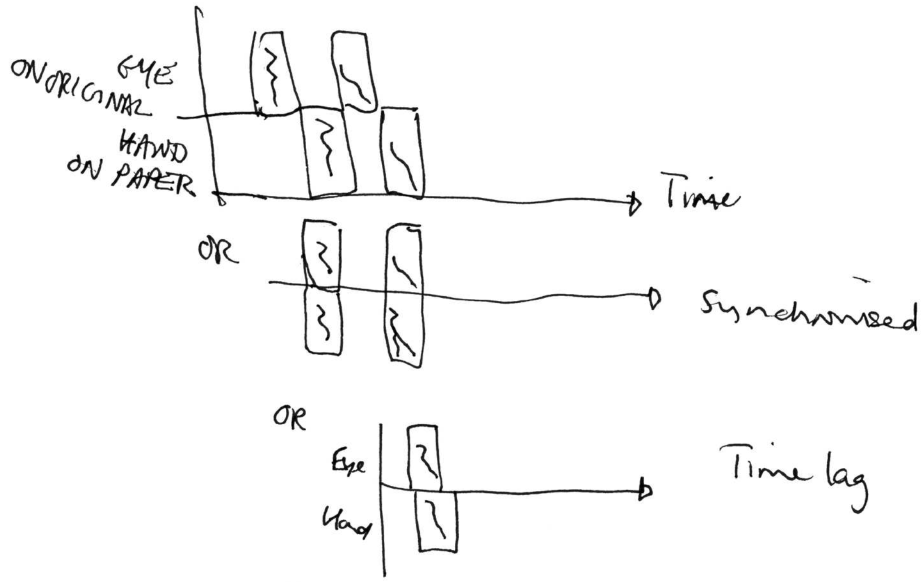
[Drawing allows discovery and generates new knowledge]

Note 9: The movement and synchronising of the hand with the eye is clearly relevant. Tchalenko states that expert copying uses a selective vision. He states that

Such a selective vision is dedicated to producing hand movements for drawing.' and that 'Only an artist drawing the portrait would perceive it as a succession of four consecutive simple lines – a perception allowing direct visuomotor transformation and providing maximum graphic accuracy

(Tchalenko 2009a p.799).

7) Does the hand follow the eye?



re selective vision, perceiving a face as a 'succession of lines'

TCHALENKO — a perception allowing direct visumotor transformation ... (2009a p 799)

SEE NOTE 9

visumotor

vision to motor

- What if we flip his statements? → — visuomotor transformation allows perception..

— selective hand movements are dedicated to producing a selective vision (Brew 2012)

TCHALENKO ON HEAD

Flipped, are equally valid

What the eye sees depends on what hand has taught it, → transformation of perception happens because of motor action

* Suggests that drawing is a dialogue — between eye and hand, and between perception and action.

Note 10:

But at a more complex level, the judgments about what lines remain to be drawn are likely to be based on how the drawing is evolving, with new lines being chosen to compliment those already drawn, or so that drawn lines may be strengthened, extended or erased to ensure the likeness is captured well. (Miall, Gowen & Tchalenko 2009 p.395)

Psychologist Chris Miall acknowledges that in reality (in contrast to tightly controlled scientific experiments) lines depend on the emerging drawing as well as on perception of the original.

Note 11: : As outlined in Chapter 2 research focus has been on the perception to action process. While Tchalenko considers the role of the hand in the drawing process his focus is on behaviour rather than perceptual function. This has meant that he has not considered the perceptual contribution of the hand. For him, and for other contemporary scientists, the sensory organs retain their traditional functions; the eye sees and the hand draws. His cognitive interpretation of drawing behaviour is based on an eye to hand model, with the eye playing the perceptual role, and with the hand acting as a motor executory agent. Physicist Coen-Cagli (2011) acknowledges the interdependence of eye and hand movements, but does not make explicit the idea that the hand is involved in perception. He considers feedback processes but does not explore the perceptual role of the hand, either using touch or vision.

They inform and correct one another. Education.

a Discussion — they move towards a closer correspondence between the drawn and the drawing.

Drawing as meta-perception; fine-grained way to test our everyday visual hypotheses

But at a more complex level, the Judgements about what lines remain to be drawn are likely to be based on how the drawing is evolving...

CHRIS MIALL

(2009 p395)

However these feedback processes are not explored in any depth by scientists.

SEE NOTE 10 FOR FULL QUOTE

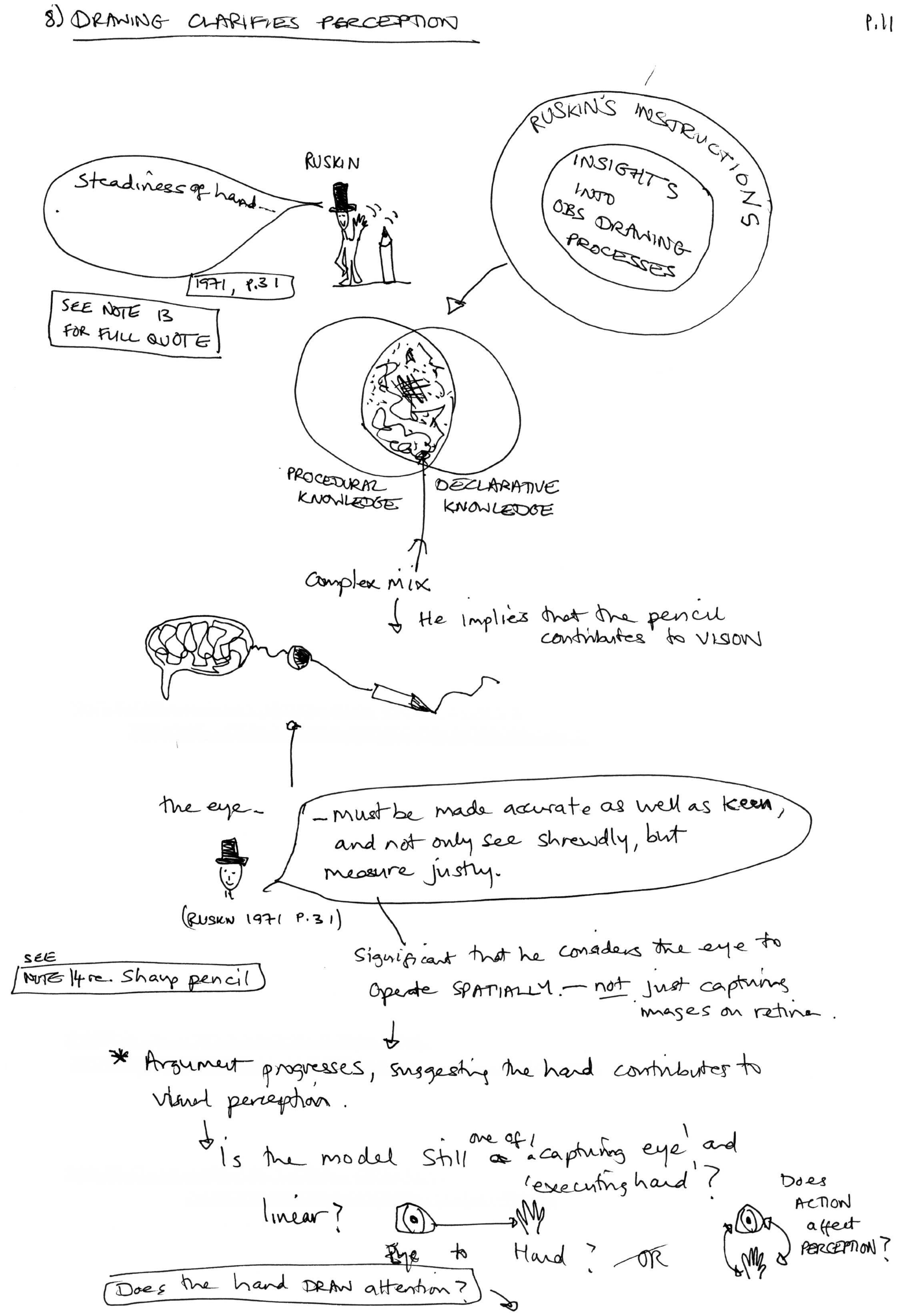
SEE NOTE 11 RE. DRAWING RESEARCH - SCIENCE

Note 13: As outlined in chapter 2 Ruskin, contrary to the common view that he thinks drawing is all about looking with the eye, emphasises the role of the hand. His first exercise in *Elements of Drawing* is about controlling the hand. He says you need 'steadiness of hand' and that the eye '…must be made accurate as well as keen, and not only see shrewdly, but measure justly.' (Ruskin 1858/1971 p.31)

Note 14: Ruskin states that

> by working over the subject with so delicate a point, the attention may be directed to the most minute parts of it. Even the best artists need occasionally to study subjects with a pointed instrument, in order thus to discipline their attention; and a beginner must be content to do so for a considerable period. (Ruskin 1858/1971 pp.28–29)

His argument is that the pencil controls attention. By this model the hand guides the eye. Does drawing proceed in a linear way from perception to action? Or does action affect perception? The concept of the hand drawing the eye to attention sits within a common model of eye and hand interaction.



8) continued.

NB

It is only by moving that the eye perceives

FINDLAY + GILCHRIST

(ACTIVE VISION 1999)

using sharp pencil

The hand draws attention

RUSKIN

it points...

By this model, the eye sees and the hand points at...

STILL AN ~~SEEING~~ / EXECUTION paradigm

however the hand is acknowledged as an attentional guide –

the hand affects perception, by drawing the eye, and drawing attention

– What work does the hand do? More than this?

Obs. drawing is reflective

about vision

versus using vision

nb What does drawing do?

– COMPARED TO OTHER ACTIONS.

Feedback models

(1) wherein the hand clarifies vision by providing lines to be assessed by the eye

OR

(2) wherein a more nuanced perceptual and motor interplay occurs

the eye and hand both contribute to visual 'capture'/perception by their movement, and a dialogue.

Note 15: Furthermore the process of drawing offers a particular way of engaging with the world, very different from everyday quick capture by the eye. The hand captures all of the line, not just distributed fixation points. As we have seen Gregory and Noë emphasise the similarities between touch and vision, and the temporal nature of looking; the way that the eye picks up information bit by bit. In observational drawing this is more evident than in other visual operations, as the eye is required to take in more detail, in order to draw. In this case a quick glance cannot capture sufficient information for the task. In this way 'looking for drawing' is more like touch than everyday looking.

Note 16: Kozbelt found that artists outperform non-artists on form recognition tasks, and argues that these results 'can be explained by the way visuo-motor skill operates in artists' methods to overcome top-down conceptual issues in object identification' (2004). They argue that the motor action of drawing contributes to perceptual accuracy. They do not discuss the exact nature of how this may occur: visuo-motor processes may be less susceptible to visual illusion. This is an issue that needs to be considered in future research. They do not specify how the action of hand may contribute to this transformation of perception. To date Kozbelt has concentrated on searching for evidence of this rather than interrogating how the eye and hand's roles may be changing within the relationship..

Note 17: This is speculative - however, it is evident that some aspects of the line we can only see through the act of drawing it; because the line does not exist until we have drawn it. In this way observational drawing is imaginative, as Gregory argues vision is. We saw above that when we turn around Tchalenko's statement about selective vision enabling hand movements for drawing and state instead that 'selective hand movements are dedicated to producing a selective vision' it still makes sense. It is interesting that his statements entertain possible validity when reversed, suggesting that the eye to hand paradigm is open to challenge.

8) continued

... while drawing I am watching and simultaneously recording myself looking, discovering things that on the one hand are staring me in the face and yet on the other I have not yet really seen.

BRIDGET RILEY

It is this effort 'to clarify' that makes drawing particularly useful and it is in this way that I assimilate experience and find new ground.

(2009, p. 20)

Riley writes that, it is as though the 'eye at the end of her pencil' .. 'tries, independently of my general purpose eye, to penetrate a kind of obscuring veil or thickness.'

(2009, p.20)

SEE NOTE 15 re MOTOR ACTION + VISUAL ILLUSION

SEE NOTE 16

TCHALENKO

His cognitive interpretation of behaviour suggests that the artist perceives the line <u>before</u> drawing —

What about:

SEE NOTE 17

Rather than action following perception, the moment when the hand begins to draw the line, a moment of action, the eye is then able to see the line ?

Some aspects of the line we can only see through the act of drawing — because it did not exist until we drew it, and it offers meaning to the visible object.

Note 18: Bridget Riley's conviction that she discovers through drawing, '…how much more you can 'see' by drawing than by just looking' (Riley 2009 p.68) represents a commonly held belief that drawing helps us to 'see'. Central to the argument is that in the particular case of drawing from life the eye needs the hand. Gregory showed how the hand elucidates ocular perception in everyday perception and tasks. In this case the hand is the key, as it is able to explore the object in a detailed way, and offer the eye information that the eye cannot capture. Perception for drawing is surprisingly akin to perception by blind people; The object is explored, bit by bit, to build up a vision of the whole – unlike everyday vision, where the eye captures key information as quickly as possible, to inform action. Leonardo's medical drawings are used by surgeons to this day, preferred over photographs, because edges and boundaries are more clearly demarcated than in everyday vision.

9) The discovering hand – why the eye needs the hand

SEE NOTE 18

how much more you can 'see' by drawing than by just looking'

Riley

Riley 2009 p68

points: draws attention to detail

helps the eye to slow down → look in more detail more closely

philosophy + science: Gregory, Gallese + Noë suggest there is more than just 'drawing attention' at play here.

There is a connection between the senses, both 'touching' the line from a distance

* Observational drawing is an unusual mode of perception – requiring extra-ordinary movements of the body.

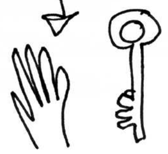
[Nb in everyday looking, the eye relies on pointing and grasping and head and body movements to clarify percepts –]

In observational perspectival drawing the head must stay still to maintain chosen view

Severe limitation

The EYE needs to find other ways to clarify ambiguities of vision.

The hand is the key. It is able to explore the object in detail,

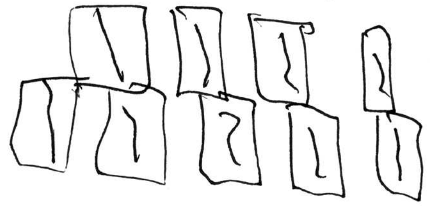


*Drawing is augmented perception informed by eye, hand movements

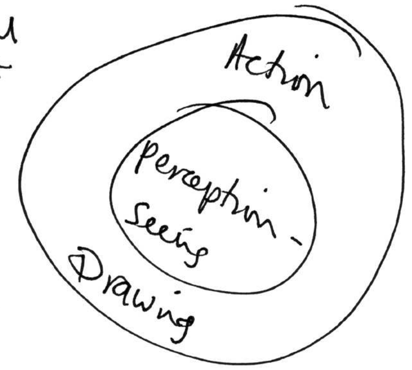
Note 19: A fundamental characteristic of observational drawing is that the hand offers feedback in the form of the drawn line. The eye checks the drawn line against the original; the eye has the chance to compare drawn lines with the external line or edge that it presents, or with a mental image. A process of continual hypothesis testing operates, using an external drawn line as a hypothesis, to be tested against an object in the world. Despite his emphasis on the eye Leonardo recognises the role of the hand in discovery, in clarifying and highlighting appearances, allowing and enhancing 'seeing'.

10) Embodied perception – Perception in action

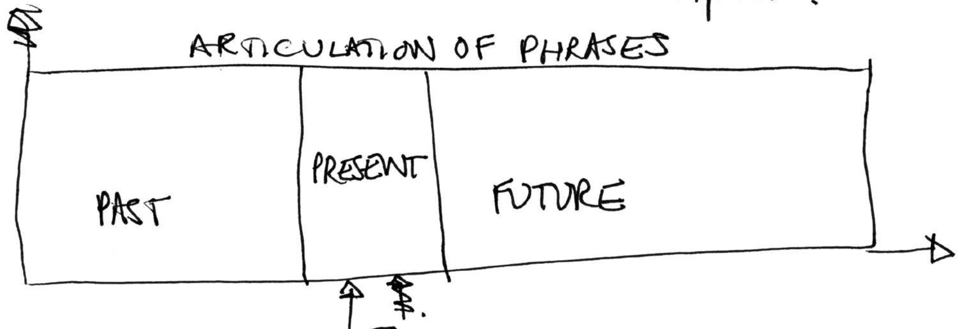
The hand rephrases – by a physical enactment
what the eye said –



and vice-versa



Closing in on a description.



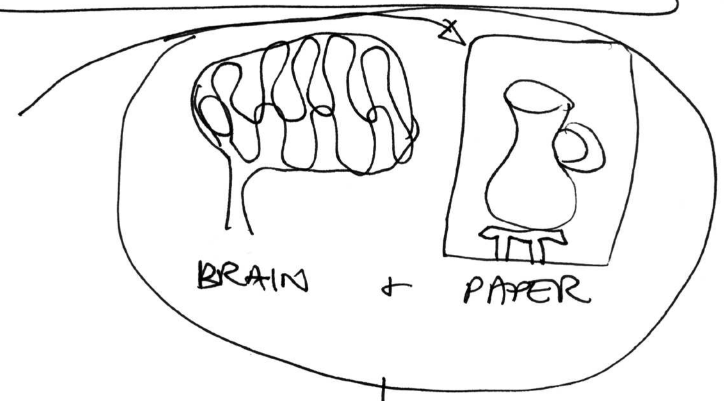
Like music...

The eye and hand simultaneously aware of what was just played, is playing, is about to play.
Listening to silences as well as sounds.

NOTE[19] re THESIS

The perceptual process occurs on the paper as well as in brain.

The paper is an external mind and memory, for figuring out things.



If the drawing is doing the thinking, does the brain have less to do?

The Drawing Mind

10) cont.

P.16

The hand certainly helps to collect visual information

whether by:

drawing the eye to attention

Slowing down the eye

OR a stronger role

THAT ~~[illegible]~~ we call 'seeing'.

The case for ~~drawing as perception~~ the hand:

It clarifies information that the eye may struggle to perceive

It shows the eye details it had missed - in its hurry, the eye jumps around...

The hand does not blindly try out a line.

Before the line is ~~drawing~~ drawn, the eye and hand are prepared to coordinate and converse

There is a feeling in the body that the eye and hand echo one another.

NB - Is this a visuomotor translation,
OR a correspondence of eye and hand movements?
i.e. motor to motor

It is likely that both translations occur, depending on method of drawing.

Note 20:

This is very important for the argument. Stabilising the percept means clarifying what we perceive, which makes it more fixed and stable, in a way giving an answer to the hypothesis that vision is testing.

Humans use multiple sources of sensory information to estimate environmental properties. For example, the eyes and hands both provide relevant information about an object's shape. The eyes estimate shape using binocular disparity, perspective projection, etc. The hands supply haptic shape information by means of tactile and proprioceptive cues. Combining information across cues can improve estimation of object properties but may come at a cost: loss of single-cue information. We report that single-cue information is indeed lost when cues from within the same sensory modality (disparity and texture gradients in vision) are combined, but not when different modalities (vision and haptics) are combined. (Hillis et al. 2002 p.1627)

We have seen that Gregory emphasised the importance of voluntary motion to give meaning to sensation. In relation to this Moffett cites Henri Poincaré, from *Science and Hypothesis,* written in 1905:

…Sight and touch could not have given us the idea of space without the help of the "muscular sense." Not only could this concept not be derived from a single sensation, or even from a series of sensations; but a motionless being could never have acquired it, because, not being able to correct by his movements the effects of the change of position of external objects, he would have had no reason to distinguish them from changes of state. Nor would he have been able to acquire it if his movements had not been voluntary, or if they were unaccompanied by any sensations whatever. (Moffett in: Kantrowitz, Brew & Fava 2011 p. 59)

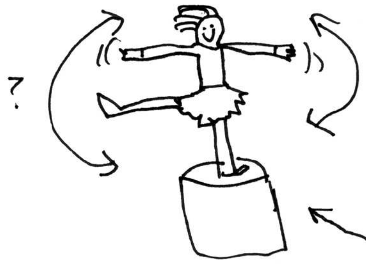
Noë emphasizes the dynamism and volition of perception, as something we do, not something that happens to us. The crucial point is that perceivers actively control what they perceive, by using movement.

Beets et al. studied how action alters perception.

UNDER THE ASSUMPTION THAT OFCOURSE PERCEPTION AFFECTS ACTION

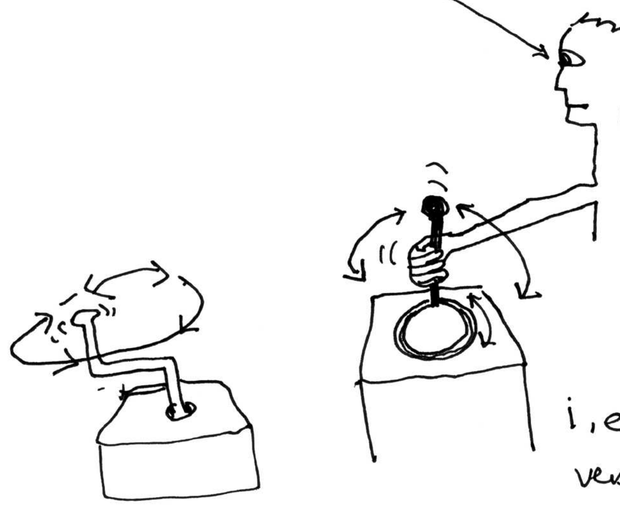
They asked: Under which conditions does action in turn influence perception?

BEETS et al. (2001, 2633)



They asked observers to view an ambiguous stimulus that could be perceived as rotating clockwise or anti-clockwise

They asked observers to rotate a handle, in one condition to match and in the other to oppose the direction they perceived the movement to be travelling in.



i.e. mirroring perception, versus contradicting it

…Our findings suggest that only percept-dependent action directly influences perceptual experience.

BEETS et al (2001 p.2633)

SEE NOTE 20 FOR details

N.b. Does it follow therefore that if one draws a 'mirroring' line it would stabilise the percept?

– It seems likely –

If so, in the same way as moving the handle, it will, in their language 'STABILISE the percept'.

i.e. directly contribute to perception

* In order to draw, the hand and eye have to work out spatial facts about the object – its orientation, edges and proportions

The eye tries to figure these things out, but sometimes cannot.

So the hand uses a differant method.

(this may be spatial cognition and/or a proprioceptive sense).

Hillis et al (2002) explain the use of multiple senses for understanding the world:

Humans use multiple sources of sensory information to estimate environmetal properties.

(2002, p1627)

e.g.

Shape?

Eyes – estimate shape using binocular disparity, perspective knowledge, etc.

Hands – Supply haptic shape info. by means of tactile and proprioceptive cues

Combining information across cues can improve estimation of object properties...

(2002 p1627)

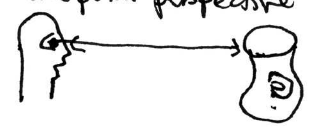
but

They go on to say that there is no loss of information when cues come from different modalities – e.g. vision and haptics.

Drawers may be combining modalities.

* However observational drawing imposes sensory restrictions on the eye; through stillness of the head required.

one point perspective



Idea that hand is required to do things the eye in this situation cannot do, e.g. depth perception by movement.

Note 21.Gallese suggests that this paradox can be solved by talking about meaning – response of the neurons can be visual *or* motor, because the response is dependent on associations – either visual or sensory information may trigger either a spatial or motor memory. This means that population of neurons can be stimulated by either a visual or motor stimulus – and internally or externally, by a memory or an actual event. 'It is our suggestion that action is one of the founding principles of our knowledge of the world.' (Gallese et al 1999 p.4).

"... sight and touch could not have given us the idea of space without the help of the "muscular sense"."

Poincaré

IN 1905, 'Science + Hypothesis

(IN Kantowitz et al.) 2001 p.59 (same ref.)

He states that a motionless being (without eye movements) is not able to 'correct by his movements the effects of the change of position of external objects...' and therefore cannot distinguish between changes in itself and the objects

Professor of human physiology

GALLESE et al

1999

paper

Perception through Action – emphasises

1999

perception – action connection, supported by findings of shared visual and motor function of neurons in fronto – parietal circuits

premotor neurons act as visual in some circumstances

he suggests the response of the neurons depends on association

visual ~~or~~ or ~~motor~~ other sensory information can trigger EITHER a visual or motor memory.

SEE NOTE 21

'It is our suggestion that action is one of the founding principles of our knowledge of the world. (1999 p.4)

Appendix 6(e) Self-portrait by author, October 2013